

REPORT

ON

FLOUR-MILLING PROCESSES.

BY

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SPECIAL AGENT.

NOTE.

The present report is the result of one of a considerable number of investigations undertaken by Professor Trowbridge and his assistants, as special agents of the Census Office, respecting Power and Machinery used in Manufactures. Other reports from this department of the census work will be found in the Volume on Manufactures, viz, those of Mr. C. H. Fitch on Interchangeable Mechanism and on Hardware, and that of Mr. H. Hollerith on the Statistics of Steam- and Water-Power. The remaining reports from this source will be embraced in a separate volume. Every branch of these investigations has been pursued under the direction and supervision of Professor Trowbridge, and according to plans prepared by him and approved by the Superintendent of Census.

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LETTER OF TRANSMITTAL.

NEW YORK, N. Y., *January 1, 1883.*

Professor W. P. TROWBRIDGE,

Special Agent in charge Statistics of Power and Machinery.

SIR: I have the honor to transmit herewith a report on the flour-milling processes of the United States in 1880.

Owing to the recent introduction of these processes it has only been possible to sketch the outlines and to hint at the various mechanical operations. Many details are still subjects of debate, and, owing to competition, a large number of similar machines have been patented, description of which would involve features foreign to the object of this report. I have, therefore, been obliged to give but general ideas of the principle of such machines.

The descriptions and drawings of mills intended to serve as examples of the latest practice were taken from the working drawings of the architects and millwrights.

The drawings from the microscopic slides were made by Mr. A. D. Churchill, instructor in drawing in the School of Mines, New York.

Yours, very respectfully,

KNIGHT NEFTTEL.

NOTE.—This report was prepared in 1880 and 1881. Since then many changes have occurred in the details of the processes, and much that was then still in its beginning is now universally accepted. The Pillsbury mill has been completed since the preparation of the report.

FLOUR-MILLING PROCESSES.

INTRODUCTION.

All great and radical changes in the methods or process of any industry have followed change in demand or supply. In their ultimate development they have often influenced reciprocally the tastes and habits of the consuming classes. We have in the milling industry the latest example of this; for, great as has been the change in process during the past ten years, it was caused by the great and rapid change in the wheat market, owing to the settlement of the northwestern states and their immense production of spring rather than winter wheat. At present flours made by the new processes are the favorites in the market.

In the old historic mills of the Brandywine, whose millers were still the subjects of the British throne, before the days of Oliver Evans, the process was exceedingly simple. The wheat, cleaned by a rude machine consisting of a couple of wire cylinders or screens and an air-blast, passed through a pair of millstones running very "low", that is, close together, in order that the greatest amount of flour might be produced at one grinding. The meal or resultant product was then bolted (sifted), the superfine flour thus separated, and the tailings, consisting of bran, middlings (coarse unground portion), and adherent flour, again separated by sifting through bolting-reels, and reground. This second product varied much among millers, some producing a fine, others a dark, impure flour, containing a high percentage of bran, and used mostly for ship-stuff, etc. It seems probable that the millers of the times, especially Oliver Evans, had some notion of the high grade of flour ground from middlings, but no systematic method of procedure was employed.

Oliver Evans (Philadelphia, 1756-1819), whose inventive genius and practical ability were, as in the case of many great inventors, but feebly requited by pecuniary success, was the first to improve materially the processes of the period. His simple contrivances, which are employed to-day in almost the same form, introduced into milling the feature that has done so much for other American industries, viz, the automatic handling of the raw material and the product in various stages by the motive power of the mill. His chief inventions were the elevator, the conveyer, the drill, the descender, and the hopper-boy. Evans says:

By means of these machines may be performed every necessary movement of the grain and meal from one part of the mill to another, through all the various operations from the time the grain is emptied from the wagoner's bag, or from the measure on board ship, until it be completely manufactured into flour, either superfine or of other qualities, and separated ready for packing into barrels, for sale or exportation. All which is performed by the force of water, without the aid of manual labor, except to set different machines in motion, etc. This lessens the labor and expense of attendance of flour mills *fully one-half.* (a)

The most important and useful of his machines, the elevator and the conveyer, are too well known to need detailed description; the former being an endless band, with cups attached to the outside, which, acting like scoops, raise the grain, meal, etc., and discharge the same on reaching the top.

The conveyer consisted, for grain, of two helicoidal surfaces on a revolving shaft, and, for meal, of a shaft with a series of small wooden blades set spirally and at an angle. These were called "flights". In both cases the contrivance was inclosed in a box, and moved the material by the principle of the screw or plow.

The hopper-boy, now no longer in use, consisted essentially of an arm revolving horizontally about an axis with flights or pieces of board set at an angle. This first spread the warm meal as it came from the millstones and then collected it to the center, where it fell through spouts to the bolts on the floor below. The angle of the flights could be changed and the motion of the meal thus regulated. The motion of the arm was slow, being not above 4 revolutions per minute.

The drill was an endless band with rakes or blades attached, and moving horizontally. It was designed by Evans to move the meal and other products in a horizontal direction. It is no longer in use, the conveyer having supplanted it entirely.

The descender, now also obsolete, was an arrangement for moving meal, etc., horizontally without the application of power. The meal was dropped upon an endless band set at a slight incline, and consisting of leather, canvas, flannel, or some other similar pliable material. The weight of the material was relied upon to produce the

necessary motion. Evans, however, recommended the application of auxiliary power to this contrivance, as there was otherwise danger of clogging. Two small buckets carried up any matter that spilled from the band and collected on the bottom of the box.

Of the benefits derived from the use of these machines, Evans enumerates the following in his *Young Millwrights' Guide*, 13th edition, pages 246, 247:

A better preparation of the meal for bolting, for packing and preserving, in much less time than usual; the work of cleaning the grain, elevating and mixing various parts to be again treated, is effected in one operation; there is considerable saving in meal;

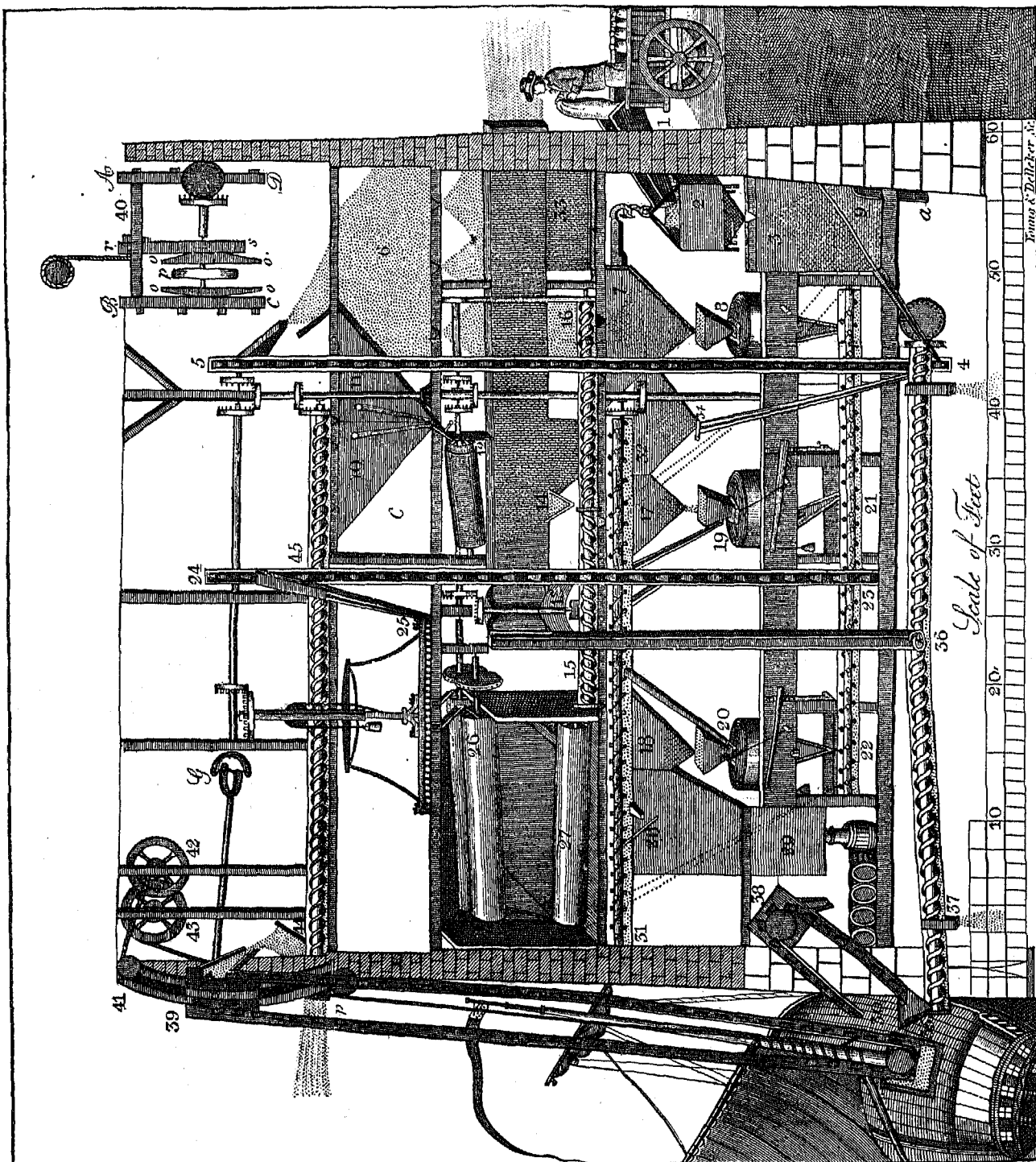


FIG. 1.

there is economy of space; the work is performed more rapidly, the elevating done with less power while preventing sudden variations of speed in the stones; and, finally, there is a great saving in cost of attendance, one operative turning out twenty barrels of flour instead of ten, as by the old method, a forty-barrel mill requiring all only two men instead of four men and a boy. The machines were durable and economical, as their motion was generally slow.

From these improvements, as stated before, dates the long period of so-called "American" milling, which produced flour as economically and of as good a grade as that of foreign millers.

As there was but little progress from the days of Evans until the introduction of the new process, about 1870, a description of the combination of his machines in a mill is here given. The cut (Fig. 1) is taken from Oliver Evans' *Young Millwrights' Guide* (Plate VIII, 13th edition), and was not given by him as a plan of a mill, but simply to show the combination and the duties of the machines.

The grain taken from the wagon 1 is spouted to the hopper-scale 2, weighed and dropped into the garner 3, whence it runs to the elevator 4 5. Having reached the top floor, it is spouted into the large storage bin 6, whence it descends by gravity to the stones 8. These break up the smut-balls and clean the grain of adherent impurities. It then returns to the bin 3, where a blast of air removes the dust, which passes out through the aperture *a*, and allows the chaff to settle. The wheat is then returned to the elevator 4 5, the crane or movable spout 5 being turned over the hoppers 10 or 11, and allowed to pass through the cleaner 12. The good wheat then falls through 14 to the hoppers 7, 17, and 18, and thence to the stones 8, 19, and 20. The ground meal from these is collected by the conveyer 21 22, and fed into the elevator 23 24, which raises it and delivers it to the hopper-boy or cooler, 25. This spreads it over a considerable surface, thus allowing it to cool, and then collects it and feeds it through the central spouts to the bolting-chest 26 27. The superfine flour is dropped in the bins 28 or 29, according to the floor on which it is to be packed in barrels.

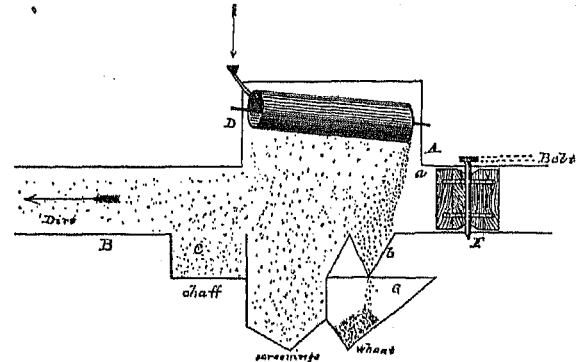


FIG. 2.

The bran, tailings, etc., are rebolted, being either returned to the conveyer 22 21, and mixed with the meal, or, by an auxiliary conveyer 31 32, are brought over the garner 18 and 17, and reground with the wheat.

The middlings or coarse-bolted meal are brought by the conveyer 31 32 to the wheat garner 17 and 18, and are reground with the wheat; 33 is a chaff-room to collect the material blown from the grain by the fan 13, the dust passing out of the mill; 32 is a garner for the screenings from 12.

These screenings can be cleaned any number of times by returning them to the elevator 4 5, spouting them into 11, 12, and 14, by means of the spout indicated by dotted lines, back to the elevator 4 5, and to the bin 10, where the process may be repeated any number of times. They are then ready for regrinding.

The second screenings being similarly purified, the last remainder may be used for cattle-feed.

The remaining parts of the figure and the design 40 refer to Evans' system of unloading ships. To use his words, "this completes the whole process from the wagon to the wagon again, without manual labor, except in packing the flour and rolling it in."

Of the component parts of the mill there remain to be described the grain-cleaning machines and the millstones. The grain-cleaner shown in Fig. 2 consists of two wire cylindrical screens, A D; the inner one, being coarser, allows all to pass but the impurities larger than a wheat-berry, while the outer one, being finer, retains the wheat and allows smaller impurities to fall into the bin. The heavy grain is discharged at *a* and falls into garner G through the current of air F B, produced by the fan F, at least 3 feet in depth.

The chaff is collected at *c* and the dust is blown out of the mill at B. This contrivance is all that was used for the cleaning of the wheat, excepting in some instances the employment of a run of stones for breaking up adherent particles of dirt.

The millstone, the chief machine of the mill, received, as may be expected, much of Evans' attention, though being at that time usually made of granite instead of the hard French burr now commonly used.

The proper "dress", that is, the furrowing of the grinding surface of the stones, was a matter which he studied, and, comparing different styles of those in use, he recommended the one shown in Fig. 3. The figure is constructed according to his directions, and shows the curved furrows in the lower or bed stone, and their relative arrangement.

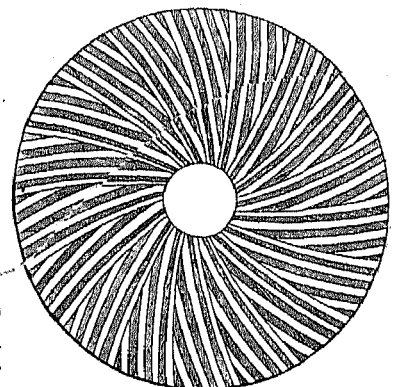


FIG. 3.

It was designed to produce the greatest possible amount of superfine flour by one grinding; in other words, to secure the complete reduction of the wheat-berry, at the same time avoiding any comminution of the bran, and cleaning it from all adherent particles of floury matter. The thoroughness with which these operations are performed depends on the sharpness of the stones and the condition of the "land", or surface between the furrows, amount of wheat fed, the distance between the stones, the speed, etc. Evans, therefore, called the attention of millers to the necessity of giving great care to the condition of the stones, of watching them carefully and constantly, "cracking" or roughening the land appropriately to the porosity, and considering them accurate machines, to be adjusted with the greatest nicety.

FLOUR-MILLING PROCESSES.

Besides the improvements mentioned above, the bolting, or separating of the meal into flour, middlings, and bran, was also modified to meet newer views, the principal innovations being the use of finer cloths, excepting on reels of 22 inches diameter or less, on which they choked; keeping the cloth free by allowing the material to fall a greater distance, which was effected by increasing the diameter of the bolting-reels to 27½ inches; the lengthening of the bolts to produce a more complete separation; and, finally, rebolting the flour to a greater extent than was done previously.

The motive power of these mills was entirely water, and was derived from the styles of wheels in use at that time—mostly tub, breast, and under- and over-shot wheels, the turbine not having been invented till 1823.

In a technological work describing the condition of the industries of all countries, published in Germany about 1843, a model American mill of the period is described as distributing the power from three breast-wheels by means of vertical shafts running from cellar to roof and from the shafts to the various machines by bolting and gearing. The above work also enumerates the advantages of American milling, which, besides including those mentioned above, gives the old-fashioned lever-packers and the crane for removing the runner-stone as characteristic improvements of the Americans.

The efficiency of the mills of his time may be surmised from the following table, given by him as the results of his own experiments: (a)

Quality of grain.	Weight per bushel.	Screenings and loss in grinding.	Breadstuff, shorts, and bran.	Ship-stuff.	Tall flour and middlings.	Superfine flour.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
White wheat, clean	59.50	1.72	13.10	2.50	3.08	38.50
White wheat, well cleaned	59.00	1.00	12.00	2.12	3.05	40.23
Red wheat, not well cleaned	60.00	7.57	8.52	1.01	3.00	38.70
White wheat, mixed with green garlic	61.00	3.08	9.54	2.40	5.08	39.70
White wheat, very clean	58.00	5.48	7.86	1.85	5.00	35.81
Red wheat, with some cockle and light grains	59.25	6.70	11.33	1.47	4.40	35.20

From this table we see that from 59 pounds of well-cleaned white wheat 40.23 pounds of superfine flour were produced. This is an exceptionally good result, and was probably far above the average. The yield, in other words, was 196 pounds for every 287.45 pounds of wheat, or a loss of 91.45 pounds. It is probable that the quality of the flour was considerably inferior to our present products.

From the death of Evans in 1819 until the introduction of the new process no great progress in method was made, though the separate machines were considerably improved, the grain-cleaning machines being greatly perfected, silk substituted for woolen cloth and other fabrics on the bolting-reels, and the imported French burr substituted for the old-fashioned granite stone. Later, the hanging and balancing of the running-stone were improved upon, and the general increase in efficiency, due to superior workmanship and better design, assisted materially in improving the quality of the flour.

The census returns of the United States for wheat produced in Minnesota, Dakota, Wisconsin, and Iowa, in 1850, 1860, and 1870, are given in the following tables, 1870 being the first year in which a separation of the spring and winter wheat was made:

WHEAT CROPS IN 1850, 1860, AND 1870 IN THE NORTHWESTERN STATES.

	1850.	1860.	1870.	
			Spring.	Winter.
	Bushels.	Bushels.	Bushels.	Bushels.
Minnesota	1,401	2,180,003	18,780,188	76,885
Dakota		945	170,400	202
Iowa	1,530,581	8,449,403	28,708,312	727,380
Wisconsin	4,286,181	15,057,458	24,375,435	1,230,909

The total crops for these states being for 1850: 5,818,113 bushels; for 1860: 26,294,799 bushels; and for 1870: 74,078,771 bushels, of which latter 2,035,376 bushels were winter and 72,043,395 bushels spring wheat.

These figures show very forcibly the main cause of the rapid extension of the new process, viz, the immense increase of hard spring wheat in the market from the northwest, and the consequent milling possibilities of that section.

This spring wheat, when ground between stones running close together, produced a dark flour, and when reduced to a degree of fineness which permitted it to pass through the finest bolting-cloths, the flour was specky. It became evident that in order to produce a first-class flour some new method must be employed, and Edmund N.

Lacroix, experimenting in the mill of Mr. G. H. Christian, near Minneapolis, invented in 1870 a "middlings-purifier", or machine for separating the dust, fluffy material, particles of bran, flour, etc., from the middlings. The principle of this machine had long been known and applied in Europe.

The middlings thus purified were reground to superfine flour, which brought more per barrel than the best flour then in the market. This led to the further development of the new process, viz, grinding the grain very coarsely, making as little flour as possible at the first grinding, producing as large an amount of middlings as possible, purifying these, and then regrinding them to superfine flour.

From the new process some millers went a step further, and adopted the Hungarian gradual-reduction system, an extension of the principles of the new process, with all its intricate mechanical details, and, it cannot be denied, with great success.

Such is a brief outline of the history of the milling art in this country.

PRESENT PROCESSES.

Before entering into a description of the processes now in use in this country, a few words should be said of wheat as a raw material, and the objects of milling.

The wheat-berry has often been described, and magnified diagrams of it have been published, but probably no enlargement is more detailed or plainer than that of M. H. Mège-Mouriès, published in a report by him to the Imperial and Central Society of Agriculture of France in 1860, and lately reprinted in the *Scientific American* supplement, April 9, 1881, No. 275. (See Fig. 4, page 6, which represents a longitudinal section through the crease.)

The wheat-berry differs much in its varieties as to composition in gluten, starch, nitrogenous matter, etc., but the anatomy of the berry is alike in all cases. Consisting of two lobes separated by a crease, it is oval in section. At the pointed end there is a light beard of fluffy material, which, with the dirt collected in the crease, necessitates the use of peculiarly ingenious machinery for its removal. It consists essentially of four parts:

No. 1 represents a superficial side of the crease.

No. 2 indicates the *epidermis* or cuticle. This covering is extremely light, 100 pounds of wheat containing about $\frac{1}{2}$ pound of it.

No. 3 indicates the *epicarp*. This envelop is distinguished by a double row of long and pointed vessels; it is, like the first one, very light and without action; 100 pounds of wheat contain about 1 pound of it.

No. 4 represents the *endocarp*, or last tegument of the berry; the *sarcocarp*, which should be found between the numbers 2 and 3, no longer exists, having been absorbed. The endocarp is remarkable by its row of round and regular cells, which appear in the cut like a continuous string of beads; 100 pounds of wheat contain about $1\frac{1}{2}$ pounds of it.

These three envelopes are colorless, light, and spongy; their elementary composition is that of straw; they are easily removed besides with the aid of damp and friction. This property has given rise to an operation called decortication, the results of which we shall examine later on from an industrial point of view. The whole of these three envelopes of the berry amounts to about 3 pounds in 100 pounds of wheat.

No. 5 indicates the *testa* or *episperm*. This tegument of the berry is closer than the preceding ones; it contains in the very small cells two coloring matters, the one of a palish yellow, the other of an orange yellow, and in proportion as the one or the other predominates, the wheat is of a more or less intense yellow color; hence come all the varieties known in commerce as white, reddish, or red wheats. Under this tegument is found a very thin, colorless membrane, which, with the testa or episperm, forms about 2 per cent. of the weight of the wheat.

No. 6 indicates the *embryous membrane*, which is only an expansion of the germ or embryo, No. 8. This membrane is here represented with imaginary spaces in white on both sides, to render more visible its form and insertions.

No. 7. The *endosperm*, or floury portion. This is composed of large cells, in which the granules of starch are found. The center is the softest part, and contains relatively the least gluten and the most starch; it is the part which pulverizes easiest under the stone, and gives, after the first bolting, the fine flour. As this flour is poorest in gluten, it makes a dough with little consistency, and is incapable of making a light, well-raised bread. The layer which surrounds the center produces small white middlings, harder and richer in gluten than the center; it bakes very well, and weighs 20 pounds in 100, and it is these 20 parts in 100 which, when mixed with the 50 parts in the center, form the finest quality of flour for making white bread.

The layer which surrounds the preceding one is still harder and richer in gluten; unfortunately, in the reduction it becomes mixed with a small proportion of the bran, which renders it unsuitable for making bread of the finest (whitest) quality; it produces in the regrinding lower grade and dark flours, together weighing 7 per cent. This layer, naturally adhering to the membrane No. 6, becomes mixed in the grinding with the bran, to the extent of about 20 per cent., which renders it unsuitable for making bread; it serves to form the regrindings and the offals destined for the nourishment of animals. This layer is, however, the hardest, and contains the largest quantity of gluten, and it is by consequence the most nutritive. We now see the endosperm increasing from the center, formed of floury layers, which augment in quantity as they are removed from the

center. Now, as the flours make more bread in proportion to the quantity of gluten they contain, it is the aim, in all the improved processes, to retain as much of the gluten in the flour as is possible, without, also, retaining any adhering bran, which injures the color of the bread even more than it does the flour.

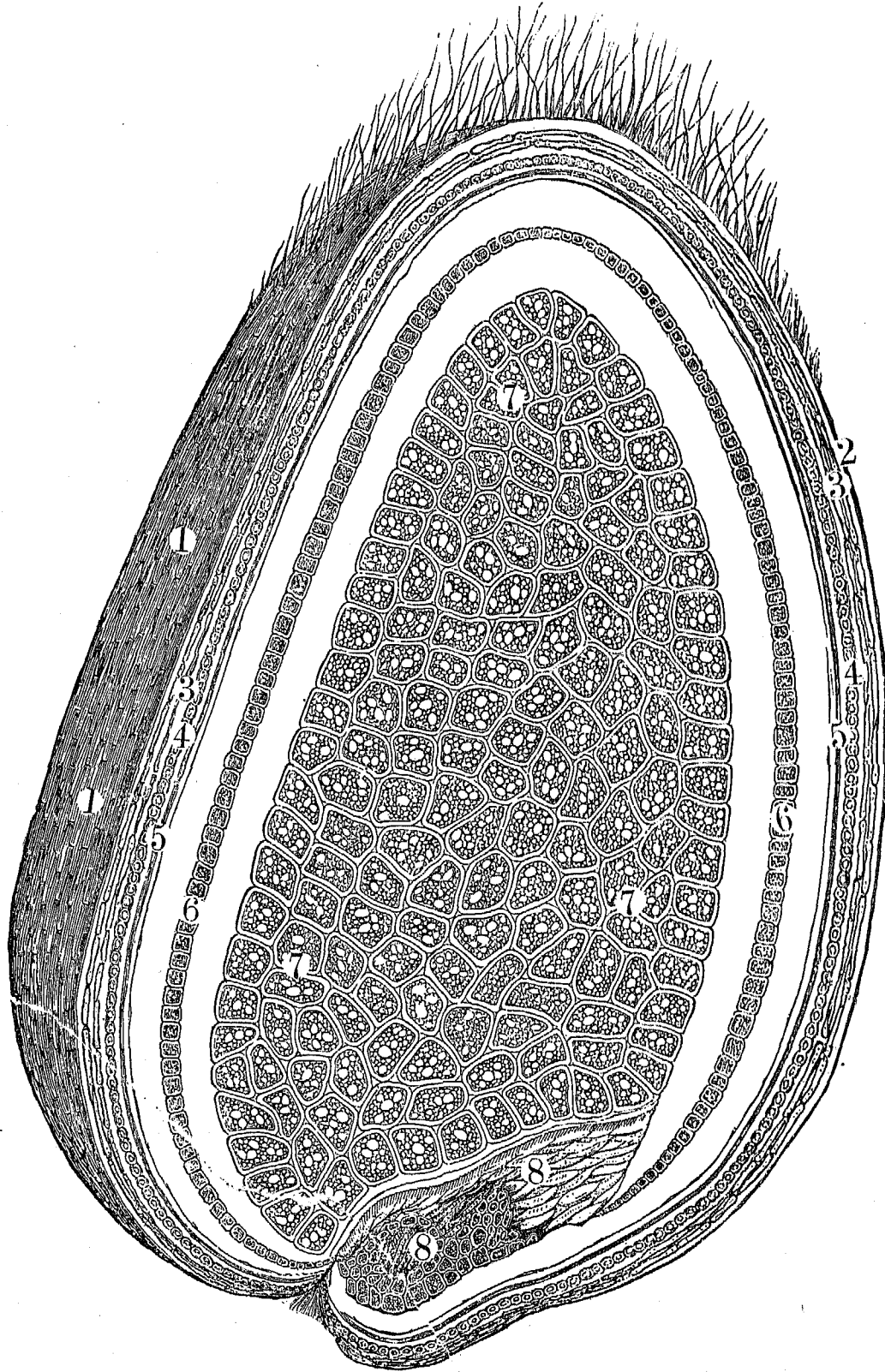


FIG. 4.

No. 8 is the *embryo* or germ, and is situated at the base of the berry opposite the crease, and is immediately surrounded by a quantity of fatty cells. Concerning this germ a prolonged discussion has arisen, as it contains phosphorus, which, being considered necessary for the human system, should, it is believed by many scientists, be left in the flour. The opposite view of the subject has, our soldier, gained foothold in this country, the "patent process" eliminating the germ from the flour, as being detrimental to its color and baking qualities.

To crush the wheat-berry to the finest possible flour, without impairing the elasticity of the flour, and to remove the bran, germ, etc., which cause the bread to bake dark, are the ends which the miller aims to attain. His process evidently must differ for different varieties of wheat, and, as indicated before, this feature has caused the great difference in present methods.

Wheat in this country varies considerably in character in different localities, and there are many varieties, there being usually a great difference between the "spring" and the "winter" grain. The former has a hard endosperm, rich in gluten, and a thin, brittle bran, which is easily broken and pulverized; while the latter is more starchy, has a tough skin, which resists grinding much more effectively than the floury portion, which crumbles easily. It is this difference in the properties of the grain that has so rapidly and so extensively brought about the introduction of the middlings-purifiers and the use of rollers. The northwestern states being the great spring-wheat producers, it is natural that the largest "new" and Hungarian process mills are located at the greatest water-power of the section, Saint Anthony's falls, at Minneapolis, and that the country in that region should be dotted with many new mills.

There are, at present, essentially three processes in operation in this country, though the details of each method vary considerably, each miller or mill-owner having his own ideas on bolting, dress, etc., and each of these processes passing by gradations into the others. These processes are commonly known as the "old process", the "new process", and the "Hungarian" or "gradual-reduction process", the latter two dating in the United States from about the year 1870.

Before describing them in their various particulars, however, it should be stated that in few industries has there been so much litigation and controversy. A great number of patents for machines with the same object in view were taken out within a short space of time; the rapid introduction of many new forms, and probably the operations of dishonest speculators, have caused many suits in the various courts of the country.

In the following descriptions, therefore, the names of manufacturers of machines and any questions of priority of invention will be omitted, as well as the question of relative efficiency of machines produced by rival manufacturers. This latter feature of rivalry is not developed more in any industry than in the manufacture of middlings-purifiers; and, in general, in all forms of milling-machines competition is extremely brisk.

THE "OLD" PROCESS.

This process, described in its earlier forms in the preceding pages, is now but rarely found in new mills, the "new" process superseding it very rapidly. Many old millers, however, still run "low", or grind the wheat in one operation. This is especially true of mills situated in winter-wheat sections and in small custom mills. The "old" process consists essentially of two parts:

- a. The reduction of the wheat to flour by passing it through a run of stones.
- b. The bolting of the resultant material and the separation of flour, bran, etc.

The principal object of the miller when running by this process is to produce the greatest amount of fine, live flour in passing the grain but once between the millstones. The exactness and perfection with which this is done depend on the following:

- a. The dress of millstone.
- b. The face or grinding surface.
- c. The balancing of the upper or runner stone.
- d. The speed of the runner.

The dress of the millstone is a subject of great importance, the proper shape of the furrows, their width and depth and draught, that is, deviation from the radius, influencing the perfection with which the operation is performed. The end to be attained is to cut the berry into small fragments, and then to crush these into fine powder, allowing the meal to pass outward from the center of the stones to the circumference as rapidly as it is reduced, surrounded by a considerable amount of air to prevent too great a rise of temperature.

If we imagine two perfectly smooth stones revolving within, say, 2 inches of each other, and wheat fed at the center, the latter would fly out from between the circumferences of the stones in an unground condition. If, however, the stones be brought nearer together, the distance between them being less than the diameter of a berry, the wheat would be crushed near the center or eye, and would choke up the space between the stones before many revolutions of the runner. It is, therefore, evident that channels must be provided for the escape of the meal, the edges of which channels would act like shears and slice each berry into several fragments. These channels are placed on the surface of both stones, and are called "furrows". The part between the furrows, called technically the "land", serves to crush into fine powder the slices or fragments of the berry formed by the furrows. These two steps form the process of grinding between the millstones, and it remains for other machines to further treat the meal.

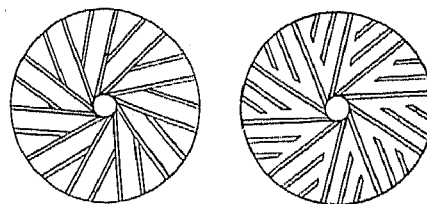


FIG. 5.

Without indorsing any particular dress or plan of furrows as the best, it may be stated that the dresses in Fig. 5 have proved efficient, and are given to illustrate the meaning of the word "dress". Opinions among millers vary much as to the details, but in general terms all agree that the furrows should be sharp, deep, and deepen gradually, dwindling to a feather-edge at the exterior.

The grinding surface or land is cracked or roughened. The degree to which this is to be carried depends, as well as the furrowing, on the porosity or natural roughness of the stone.

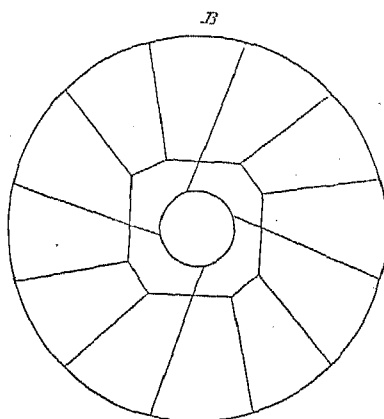
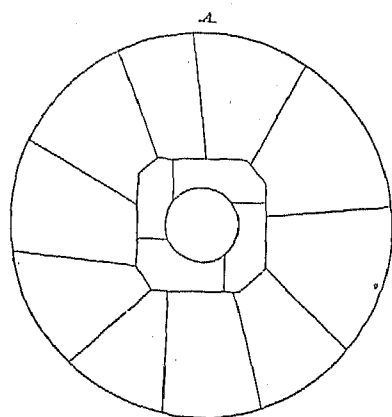


FIG. 6.

As the millstones now in use are almost invariably of the French or of the Georgia burr, a porous metamorphosed sandstone, containing cavities formerly occupied by fossils, the surface is variable, and each stone is usually built up of several blocks, as in Fig. 6, to insure an even degree of porosity over the whole surface. The blocks are arranged in different ways, B showing a construction by which the joints are so placed as to coincide with the furrows.

Another feature of prime importance in the case of millstones is a perfectly plane surface in both stones. It is evident, in order that the product may be uniform, that the same condi-

tions should prevail over the whole grinding surface. If there be any variation from a perfect plane in either of the stones the meal will contain large unground fragments and the grinding will be incomplete. The necessary surface is produced by removing the higher portions with a steel pick, and frequently testing with a straight-edge, called a "paint-staff". A proof-staff, a narrow iron rectangle having a perfectly plane face, is usually kept in the mill to

correct any shrinkage or variation in the paint-staff. The latter, while coated with fresh paint, is rubbed over the surface, and the higher portions are thus determined. These are worked down by small picks or other tools until every portion is reduced. Too great care cannot be given to the dressing and facing of the millstone, and this should be attended to very frequently. As may be naturally inferred, the general features of the furrowing and cracking depend on the variety and condition of the wheat to be ground, and here the experience and judgment of the miller come into play.

The balancing of the upper or running stone is a subject of importance, as, however true the face and efficient the furrowing may be, if the stone does not run truly horizontal the product will be uneven. It is, of course, premised that the lower or bed stone should be accurately leveled.

The usual manner of hanging the upper stone at present is shown in Fig. 7. A is the end of the spindle or vertical shaft, upon which rests the pivot B, thus allowing a free motion around A, and a single point of suspension. The mechanical details are easily seen from the figure. The lever C enables the runner-stone to be raised. Several other styles of hanging are in use but the principles involved are the same.

Like all masses when suspended on a pivot, the millstone has two conditions of equilibrium, called commonly the "standing" and the "running" balance. Each is independent of the other; that is, if a stone be in a horizontal plane when standing, it may not remain so when rotated about its axis, and, conversely, if horizontal when rotated at a certain speed, it may not be so when at rest. This mechanical truth involves the use of the contrivances shown in the upper corner of the running stone. These are simply iron pots into which shot is poured, or a weight moved vertically

by a screw. By either means the plane of rotation is changed, and the surface is brought to a perfect level, so that the grinding surfaces may operate uniformly over their entire area.

The fourth and last consideration is the speed of the stones. It being the object of this process to produce as much flour as possible at one grinding, the speed of the stones is much greater than in the other processes, sometimes reaching as high as 300 revolutions per minute. This, however, is exceptional, and the average is rarely over 250, too high a speed producing a high temperature, deleterious to the meal. The speed varies according to the dress and according to the grain to be ground.

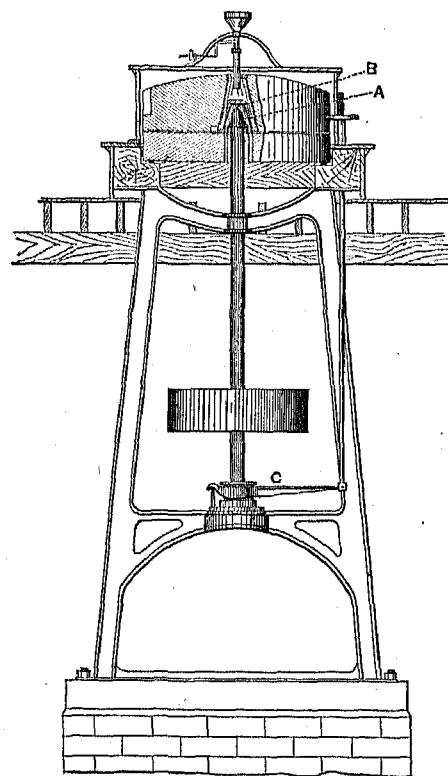


FIG. 7.

The second part of the "old" process is the bolting or the separating of the flour from the bran and coarse matter. The machine, called a bolt, by which this is effected consists of a cylindrical frame of wood, some 18 feet long and about 30 inches in diameter, covered with a silk bolting-cloth sewed to ticking, which is in turn tacked to the longitudinal pieces of the frame. The cloth, now in every case silk, is of various degrees of fineness according to the material to be bolted. Generally four bolts are inclosed in a frame, two for bolting and two for rebolting, called "return bolts". The whole arrangement, called a chest, is shown in Fig. 9, page 10. The flour thus separated is packed without further treatment. This process, though essentially the same in principle as that of Oliver Evans, is considerably more efficient, owing to the following improvements introduced since his time:

- a. The change from poor bolting-cloths to nicely-woven silk bolting-cloths.
- b. The greater accuracy in the adjustment and running of the stones.
- c. The greater efficiency in grain-cleaning.
- d. Better devices for packing the flour in barrels.
- e. The general improvement in all parts of the mill, due to better workmanship and design.

The use of silk bolting-cloths permits a finer and more complete bolting and increases the efficiency of the mill to a very appreciable extent. The greater accuracy of adjustment in running of the stones produces more and finer flour from the grinding, and the improved packers enable a more economical packing as respects time, labor, and flour. A description of the present grain-cleaning machines is given in the following pages. The system of "low grinding" is giving place, as previously stated, to the "medium high-grinding" or "new" process in new mills, even in soft-wheat sections.

THE "NEW" PROCESS.

The process consists of four parts, the features of purifying and regrinding middlings being added to the first grinding and bolting. As in the other processes, a complete and thorough grain-purification is necessary.

Briefly outlined, the process is as follows: The perfectly clean grain is conducted to the burrs and "granulated", not ground, as in the previous process, and the resultant "chop" is separated into its component parts—flour, middlings, and bran—by means of bolts technically called "scalping-reels". The flour thus produced is of an inferior grade. The middlings are the coarse particles of the endosperm of the berry, which give the strongest and best flour, and it is from these that the "patent" or high-grade flour is made. The bran and dirt from the crease of the berry, which will remain, however good the cleaning, are separated out; the middlings, usually by the cloth near the tail ends of the scalping-reels, are then dusted in dusting-reels and conducted to the middlings-purifiers, which remove all light fibrous matter, fuzz, etc. They are then graded and reground to flour, either on separate stones, or mixed with other wheat. The former is the more approved method.

As soon as the principle of the purification of middlings was introduced into this country, the idea was realized by a great number and variety of machines. Indeed, so many machines are now in the market, whose efficiency varies but little, and the rivalry is so great, that it will be impossible to describe the various forms of the machines or to give any illustration of a particular variety in a report of this nature. The end sought is to extract the lighter material, the dust, bran, and fuzz mixed with the middlings, and to leave the latter clean and pure.

The various contrivances may be divided into any number of classes according to their mechanical details; but a subdivision into the air-and-sieve and the electric machines will cover all cases. The former and usual form of

purifiers consists essentially of a series of sieves in connection with an air-blast, the former being to separate the middlings and the tailings, and the latter to remove the lighter impurities. I have constructed the diagram, Fig. 8, as showing the essential parts of the air-and-sieve class of purifiers. The impure middlings are dropped into the chest through the hopper A and fall upon the sieve b; from b they slide to c, and from c to d, whence they fall off and are spouted out at e. The fans f and g cause a draught through the sieves, and as the material passes through the air in its descent, the light matter is removed

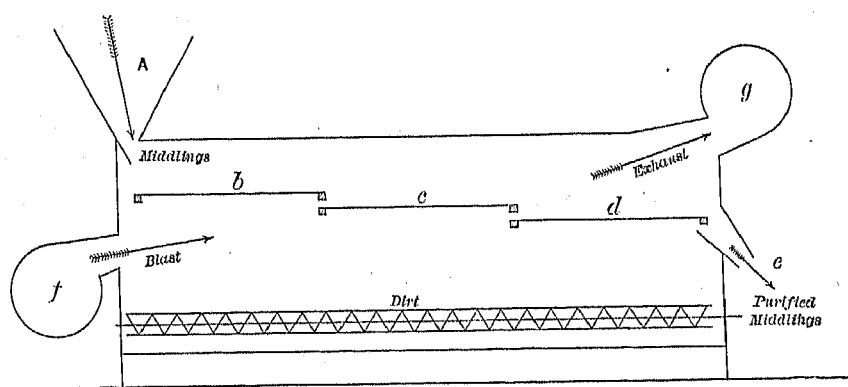


FIG. 8.

while the tailings drop beneath. These are the chief elements of a purifier, though present forms are much more complicated. In some machines the draught is produced by a suction-fan alone, in others by a blast alone, and again in some by a combination of both varieties of fans, as in Fig. 8. Some forms of the machines contain reels for dusting the middlings before purification, while in others no provision is made for this preliminary step.

In order that the separation may be complete the sieves are agitated, and this is done in a variety of ways. The sieve-frames are given a rapid reciprocating motion by an eccentric and pitman contrivance, or light hammers strike small cloth pads on the sieve-frames, and thus give a short, sharp rap, which raises the stuff from the sieves.

and spreads it for the air-blast. Several other forms are used for the same object. Early in the use of purifiers a difficulty arose, which, however, was soon obviated, namely, the clogging of the sieve-cloths, owing to their flat surface and the nature of the product to be treated. At present many devices are used for preventing this, such as traveling brushes, elastic bands which strike the cloth, traveling blasts, which, it is claimed, do not wear the cloth, and rubber balls bouncing between the sieves and a wire net.

These various methods for insuring the same results explain the large number of patents issued for purifiers and the great number of machines of various makers.

As previously stated, many lawsuits have been caused by the rapid invention and introduction of various milling-machines, and there has been a prolonged legal strife, involving many millions of dollars, concerning the manufacture of middlings-purifiers.

The so-called electric purification of middlings, due to the property of attracting light material existing in electrified surfaces, has taken considerable prominence lately, and there is a question of priority of invention.

Of the two machines of this kind recently exhibited, one consists of several vulcanized-rubber bands running over pulleys, passing over the surface of the middlings, and thus removing all the lighter portion of the material; the band is excited by pads rubbing against its surface. In the other machine rubber cylinders revolve over the middlings and similarly attract the impurities. Should this apparatus be found in practice to work as well as the sieve-and-air machines, it will have some advantages, such as economy of space, obviating the somewhat cumbersome use of fans, clogging, and wear of cloth.

Besides these forms, several designs of purifiers have been introduced which do not fall in either class, but depend on gravity to cause the necessary separation.

The comminution of the wheat in the new process is granulation, not grinding; that is, the endosperm of the berry is not reduced to flour in its first passage between the millstones, but is simply crushed and liberated from its covering of bran.

The smaller the amount of flour made during this operation and the coarser the fragments (*i. e.*, middlings) of the endosperm, the greater the subsequent yield of "patent" flour. It is evident, therefore, that dress, speed, distance apart, etc., of the millstones must be very different from the corresponding features in the "old" process stones.

The present practice in the "new" process burrs is to make the furrows from 1 inch to 3 inches wide and sometimes to the number of 70 on one stone, the object being to reduce the "land" or grinding surface; some millers even advocating a perfectly smooth "land", while others believe in a certain amount of cracking.

The theoretically perfect dress and face have not yet been determined, the matter being still in active debate.

The speed of the burrs has been materially decreased, and instead of 200 or 300 revolutions per minute, the "new" process millstone revolves on the average 140 turns per minute, in some cases even below 100, and takes about one-half of a horse-power instead of one horse-power as before. With this decrease in speed the diameter of the stones has also been diminished from 6 to 4 or $4\frac{1}{2}$ feet, the object being to allow the material to escape as soon as granulated and to reduce the production of first flour to a minimum. Stones of these dimensions and running at present speeds, 140 revolutions per minute, will granulate about 5 or 6 bushels an hour. This is considerably less than the amount ground by the "old" process on one reduction, but the superior product in the end compensates for the lesser quantity.

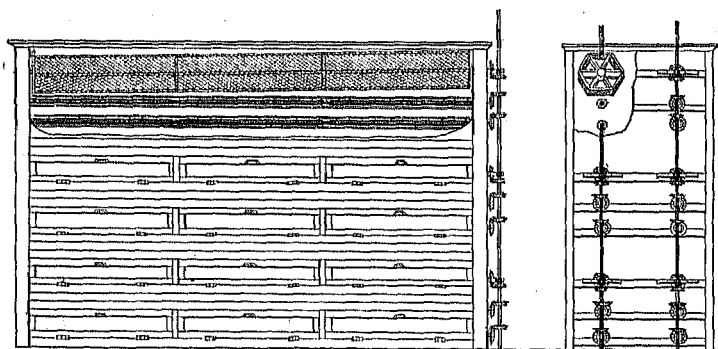


FIG. 9.

The quantity of middlings varies greatly, according to the dress and the conditions of the stones, the wheat

used, etc., the limits being about 40 and 70 per cent. To produce one barrel of the best flour, from $4\frac{1}{2}$ to 8 bushels of wheat are used.

The grinding of the middlings to flour is usually effected on stones, though rollers are rapidly coming into use for the same purpose. When stones are used, the furrowing is shallow compared to that on the granulating stones, as the material to be reduced is smaller in size.

At some mills the wheat and middlings are mixed together so as to pass through the stones at the same time, while at others the middlings are carefully graded and reground on separate runs of stones. The number of grades to be made is as yet a matter of debate.

The principal innovation in bolting in the "new" process is a considerable reduction in the size of the reels, the average dimensions being from 16 to 18 feet long and 30 inches in diameter. In some cases reels but 12 feet long have been used.

Fig. 9 gives an end and a side elevation of a bolting-chest, one part of the casing being left open to show the bolt and the two conveyers. Between the conveyers and the reels is a series of flat slides called "cut-offs", which facilitate the regulation of the bolted material from the cloth to the conveyers.

The reels and the conveyers are usually operated from one vertical shaft by small gears about a foot in diameter. The sides of the chest are inclined hopperwise to allow the flour, etc., to slide down to the conveyers.

In the figure the whole is inclosed in a case, as is often done in practice, with swinging doors to allow access to the various parts.

The hexagonal cross-section of the reel is shown in the side elevation. The silk bolting-cloth is imported mostly from Switzerland or the Netherlands, the brands made in those countries being usually considered the best, but bolting-cloths claimed by the makers to be equal to any imported silk are manufactured in this country.

The cloth for the various separations ranges from "000", or 780 apertures to the square inch, to the finest, "No. 13," having 18,496 apertures to the square inch.

This system of grinding, preventing as it does any considerable development of heat, obviates the necessity of any cooling arrangements and two inconveniences of low-grinding, viz, the "sweating" of the burrs—that is, the production of moisture during grinding—and the pasting or choking of the bolting-cloths. Several devices have, however, been introduced to keep the cloths open, such as whips and straps extending through the interior of the reel, and removing the matter caught in the meshes of the cloth by sharp raps. An objection to the use of these appliances is a certain amount of wear on the cloth.

The chest in the figure contains six reels, three being vertically in line, one above another.

Before leaving the "new" process something should be said of several appliances which have greatly facilitated the work of the miller and improved the quality of the product, but which do not necessarily form part of the process, and have been applied to "old" process mills as well.

It having been noticed that wheat when damp is ground into a flour containing too much moisture, deleterious to its treatment, its transportation, and to its baking qualities, a system of drying has been introduced, usually by steam, prior to the grinding.

This plan, it is claimed, will produce an appreciable improvement in the products, and has been introduced in a number of mills. Another scheme, but not so successful in its result, is the steaming of the wheat, the object in view being the toughening of the bran to prevent its too fine comminution.

Another valuable contrivance is the bran-duster, which saves a considerable amount—from 1 to 5 per cent.—of flour. This machine usually consists of a cylindrical or conical brush in connection with a wire sieve, the bran remaining on the inside and the brush forcing the flour through the sieve. Several other designs have been introduced, but this is probably the most widely used.

The artificial ventilation of millstones, another new improvement, has proved to be a success, in preventing fire from spreading from sparks caused by millstones running empty, and penetrating into conveyers, etc. It has been applied in the latest gradual-reduction mills on their regrinding stones. The air is withdrawn from the circumference by suction, and the resultant draught in the furrows tends, besides the above advantage, to prevent any undue rise in temperature of the material ground.

The packer, another improvement, is shown in outline in Fig. 10.

It consists of a cylinder of wrought-iron into which the flour, bran, or other material to be packed is fed, and by means of the screw-blade A is forced into small bulk in the barrel or in bags. When different sized bags are to be packed the cylinders B are changed, a number of different sizes being kept to fit the bags. An outer casing of iron is put around the bag to keep it in place. As the platform descends the weight rises, thus representing the pressure on the flour. Roller packers and some other forms are also used, but the form described above is used to the greatest extent.

We have now followed out the "new" process in its steps from the cleaned wheat to the packed flour.

While a fine quality of flour can be made from purified middlings, that is, the part of the berry richest in gluten, from either spring or winter wheat, many millers of the old school still believe that a single reduction is practically sufficient. It is undoubtedly true that for small mills of not over two run of stone, and for mills running on very soft wheat, the two processes may approach each other in efficiency, but the purification of the middlings and the production of "patent" grades have been established as undoubted improvements, and it would be impossible for spring-wheat mills to produce a flour approaching the best winter-wheat brands without the principle of regrinding middlings. At present these mills are producing flour rating higher in the market than any low-process mill.

There now remains to be described the third or gradual-reduction (often called the Hungarian) process, which is an extension of the principles of the "new" process.

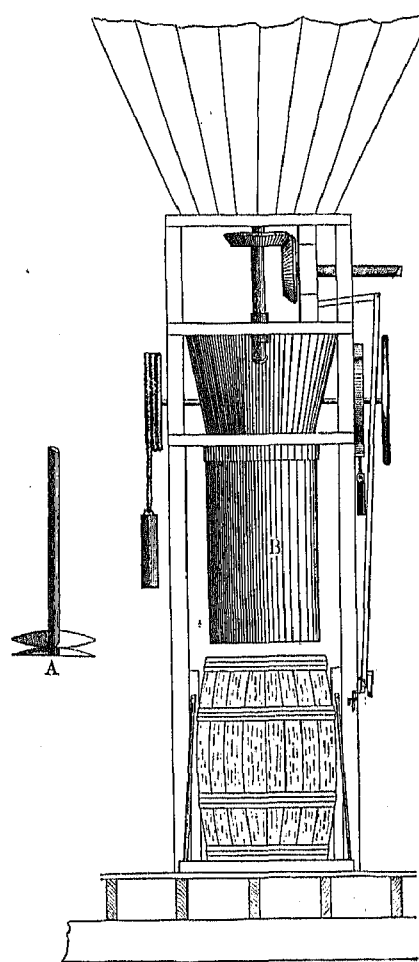


FIG. 10.

THE GRADUAL-REDUCTION PROCESS.

This process has been adopted in the mills recently erected in the spring-wheat sections of the northwest. Its greater mechanical complication, and the large number of steps from cleaning to packing, cause it to be of greater interest to the mechanical engineer, and several portions of it, although adopted by "new" process mills, have not been described in the section pertaining to the "new" process.

The process, reduced to its essential features, consists of—

- a. The cleaning of the grain.
- b. The granulation of the wheat.
- c. Separating the resultant products.
- d. Reducing the fragments of the berry, again separating, and further reducing the fragments, usually five or six times.
- e. Purifying the middlings from these various reductions.
- f. Grading and regrinding the middlings.
- g. Bolting.
- h. Packing.

From the nature of the process, the larger the mill the more economy in the manufacture; and for small mills the "new" process is probably as efficient.

The principles of the process, introduced into this country during the past four or five years, were taken from the practice of Hungarian millwrights.

Many American millers have visited the cluster of mills at Buda-Pesth, the principal home of Hungarian milling, where the wheat is of a very similar nature to our northwestern varieties, and the process is now used in the largest mills of Minneapolis.

Starting with the cleaning of the grain, as it is delivered to the mill, to the final shipping, a description is here given in as much detail as the scope of this report will allow.

The perfect cleaning of the wheat-berry before reducing it, both as to its surface and as to foreign matter mixed with it, is a subject of great importance, and a large number of machines have been devised for the purpose.

All varieties of grain-cleaning machines fall into two classes:

- a. Those for separating the wheat from loose foreign matter, such as cockle, oats, chips, iron, wire, etc.
- b. Those for removing adherent matter and leaving the bran polished, the fuzz at one end removed, and the dark matter usually found in the crease extracted as far as possible.

Machines for extracting the loose foreign matter, usually termed separators, consist generally of riddles or screens and an air-blast or suction to remove light impurities. The number of separations varies; sometimes as many as four are combined in one machine. The separator is often combined with scourers, and the wheat is almost entirely cleaned in one machine. It is usual, however, in large mills to employ, first, storage separators, designed to treat large amounts of wheat, then wheat-separators, and finally cockle-separators. The most approved design at present is to place the screens, with apertures of the shape of the impurities, and often inclosed in a wooden chest, so that the wheat descends from one to the other by gravity and by the reciprocating motion of the screens. The blast is produced by a suction-fan and the dust is blown out of the mill.

A great variety of machines for cleaning the berry of adherent matter have been introduced during the past 15 years. It will be impossible to specify here more than the general principles involved.

The wheat in these machines is usually cleaned of adhering matter by friction, either of the kernels among themselves or with some foreign substance, such as stone surfaces, brushes, etc. A draught, usually caused by a suction-fan, removes the dust as it is formed.

A usual form of scourer consists of a series of vertical rods revolving about the axis of a cylindrical steel jacket, and operates by the resultant attrition of the berries among themselves, and against the rods and the surface of the cylinder.

Another form much used is the brushing of the grain, either between two revolving cylindrical or conical brushes, or between a brush and some other surface; this polishes the grain and leaves it ready for grinding.

Stone surfaces for the same purpose, viz, polishing, have also been employed.

The present typical separating and scouring machines are usually vertical, with vertical axes. The machines are set directly one over another on the various floors, and one shaft usually moves those in one mill. The power required for cleaning varies with the machines, the scourers requiring more than the separators.

The separators handle from 10 to 1,800 bushels an hour; the scourers, brushes, and combined machines from 10 to 300 bushels an hour.

As may be expected, these machines vary from the simplest wind trunk and sieves to the complicated separators, smutters, and scourers combined in one machine.

Many small devices have been introduced to further purify the grain and polish the berry, such as magnets set in a spout to extract iron, nails, wire, etc., from the stream of wheat.

The great contrast between the cleaning appliances of Oliver Evans' time and the complete series at present in use in our large mills is apparent. At present no miller considers his mill complete unless he can remove entirely all chaff, cockle, etc., from his wheat before grinding, polish the bran of each berry, and remove the dark matter from the crease.

Another operation introduced in the grain cleaning is the so-called "ending", that is, shearing off of the beard (Fig. 4) of the berry. This is done on a run or on several run of stones, according to the size of the mill, the stones running far apart and so adjusted as to remove simply the extremities of the berries, which are then passed through wire-cloth bolting-reels and are ready for the "gradual reduction". In this the millstones are wholly or

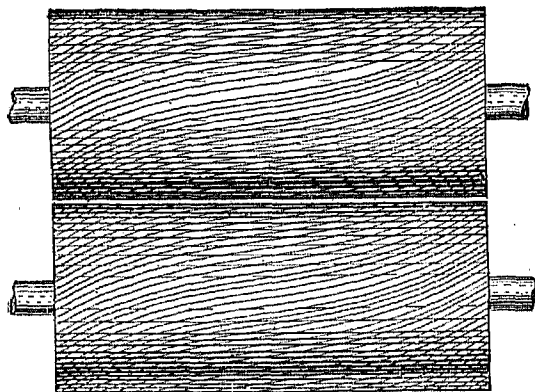


FIG. 11.

in part abandoned, and the work is done by means of grooved and plain rollers (invented in Switzerland about 1820), made of chilled iron or of porcelain. In some cases disks of chilled iron, suitably furrowed, are used, and in others concave machines, consisting of a cylinder running against a concave plate. The system consists in reducing the wheat to flour, not at one operation, as in the "old" system, nor in two or three grindings, as in the "new" process, but in several successive reductions—four, five, or six, as the case may be. The wheat is first passed through a pair of corrugated chilled-iron rollers, which merely split it open along the crease of the berry, liberat-

ing the dirt which lies in the crease so that it can be removed by bolting. 2, Fig. 12. A very small percentage of low-grade flour is also made in this reduction. After passing through what is technically called a "scalping-reel" to remove the dirt and flour, the broken wheat is passed through a second set of corrugated rollers, by which it is further broken up (each such operation is technically called a "break"), and then passes through a second separating-reel, which removes the flour and middlings. This operation is repeated successively until the flour portion of the berry is entirely removed from the bran, the necessary separation being made after each reduction. The middlings from the several reductions are passed through the purifiers, and, after being purified, are reduced to flour by successive reductions on smooth iron or porcelain rollers. In some cases, as stated above, iron disks and concave mills are substituted for the roller-mill, but the operation is substantially the same in principle.

The rollers for reducing are of various forms, a lively competition having arisen in this country since their introduction. A complete machine for granulating usually consists of four rollers, in sets of two, with a double hopper above. Each roll is of chilled iron, rifled or fluted, with spiral corrugations. A section of a pair with sharp projections is shown in Fig. 11.

One roller revolves faster than the other, the differential speed thus produced enabling the projections of one to shear the berry caught in the projections of the other, and thus affect its granulation. Each form of corrugation, round, sharp, etc., is praised by its maker.

The rollers are either geared or belted together, the latter causing a quieter motion, while the former, it is claimed, prevents any slipping or inequality in the relative speeds.

At the present writing the roller-machines have attained such perfection, especially as to adjustment, ease of throwing in and out of operation, and perfection of workmanship, that it is extremely doubtful whether any foreign nation, Hungary included, has better or more efficient machines.

Several devices have been adopted for the adjustment of the rollers, so that they may be suddenly separated when starting or stopping; also, so that, in case of any foreign matter entering with the wheat or material to be ground, the rollers may separate of themselves and allow it to pass.

The usual design is to make the bearings movable and arrange them in such a manner that the two rollers are pressed together by springs.

The power necessary to drive a four-roller machine is claimed by makers to be nearly one-third less than that necessary for a millstone granulating the same amount per hour.

The details of feed, gearing, belting, etc., have been brought to a high state of perfection, but they cannot well be given here.

In some mills the first break consists of runs of stones running very high (far apart), the other reduction being on rollers; and in some other mills certain of the last reductions are also made with stones. Various arrangements of detail are now on trial.

From the first boltings succeeding the scalping-reels in the first few breaks the greater part of the oily germs are separated, and, with the tailings from these reels, are aspirated and reground on smooth iron rollers. These flatten the germ, and it is separated in the succeeding boltings.

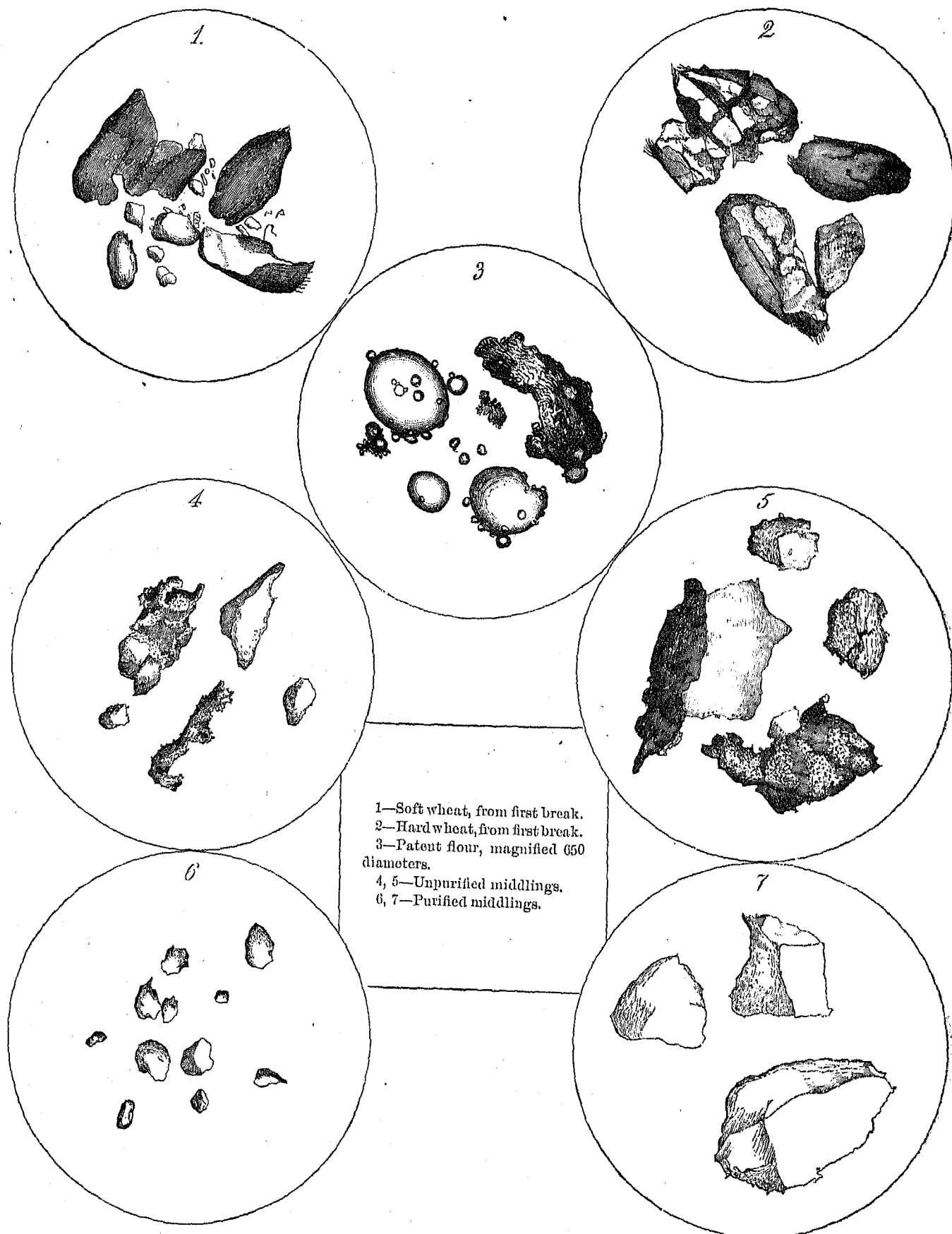


FIG. 12.

The best grades of middlings produced are often reground between porcelain rollers.

All the various regrindings are separated and handled by bolting until the various grades of flour, about five or six in number, are ready for the packers. These are of the form described on page 11, and are of great mechanical perfection.

To show the effect of the various machines on the wheat, Fig. 12 has been prepared from samples taken from Minneapolis, Minnesota, and from Richmond, Virginia. No. 1 is the broken soft wheat from the first break, millstones being used; 2 is the same for hard wheat broken on rollers (the lesser comminution of the latter is plainly visible); 4 and 5 are unpurified middlings from soft and hard wheats respectively; 6 and 7 are purified middlings from soft and hard wheat; and 3 is patent flour. This latter is magnified to 650 diameters, while the other figures are much less magnified.

At present, in a perfect gradual-reduction mill, about $4\frac{1}{2}$ bushels of good spring wheat are needed to produce one barrel of flour (196 pounds), 74 pounds of feed being made at the same time.

The quotations in New York for various flours on June 1, 1880, were as follows, showing the preference accorded "patents":

Western spring extras	\$4 00 to \$4 20
Minnesota clear	4 25 to 5 40
Minnesota straights	5 50 to 7 35
Spring-wheat patents	6 00 to 8 00
Winter-wheat seconds	4 50 to 4 75
Spring-wheat extras	4 50 to 4 60
Saint Louis flour	5 10 to 6 00
Winter-wheat patents	6 00 to 8 20
Southern flours	2 00 to 6 00
Northern flours	2 40 to 8 60

Besides the processes described above, several individuals have introduced systems of their own, of which they have patented the principal features. Their mills, of which a number have been built, are all essentially gradual-reduction mills, but the details of handling vary. Among this class may be mentioned the "degerminator", or metallic millstones with rounded furrows, allowing the germ to drop out of the split berry before it is crushed; a system of wind trunks to gather the dust from the purifiers in the mill; a granulating mill, consisting of a hollow cylindrical stone, with a runner inside, the grain being crushed between the concave surface of one and the convex surface of the other; and many innovations in bolting, such as elaborate systems of rebolting and separating.

Many of these devices are probably efficient, and may be applied with gain to the user, but a longer practical use is necessary to determine their respective values.

Two small forms of apparatus, however, which have been introduced lately, will probably tend to a better knowledge of milling products. One, the molarimeter, invented by Edward Campbell, consists of a bent thermometer, the bulb of which projects into the stream of meal from the millstone, the temperature of the meal being shown on the stem. Several points previously suspected are confirmed. It is found that different varieties of wheat can endure different degrees of heat, that the temperature varies with the grinding surface, etc.

The other device, the aleurometer, measures the relative elasticity of the gluten extracted from the flour by means of a piston moving in a cylinder.

The combined use of these two appliances has yielded the following table, which appeared in the *American Miller*, Vol. 6, page 33:

Temperature of flour ground, indicated by molarimeter. Degrees F.	Elasticity indicated by aleurometer. Degrees.
90	48 $\frac{1}{2}$
104	42
110	38 $\frac{1}{2}$
120	34

From these figures it appears that the flour produced at the temperature of 90° Fahr. yields the most elastic gluten, indicating the strongest flour.

In order to complete the account of gradual reduction, two mills will be described, one being partially in operation and the other in process of erection.

THE "WASHBURN A" MILL.

Among the mills at the falls of Saint Anthony, the largest and most prominent, the Washburn A, is an example of the latest application of the gradual-reduction process, and illustrates the magnitude which single mills and milling operations have attained. The site now occupied by the handsome and imposing structure is that on which the great explosion (1878) destroyed the old Washburn A, badly shattering the adjoining mills, and killing

and maiming a large number of persons. The mill is shown in Plates I and II, Plate I being a longitudinal elevation, and Plate II an end elevation. The building is 100 feet wide by 244 feet long, eight stories high, about 158 feet from street to cupola, built of masonry, and resting on the solid rock.

The floors are supported by vertical pillars between walls, the girders resting on cast-iron plates, to prevent settling. The various stories vary from 14 to 18 feet in height. A brick fire-wall divides the mill into two parts, one called the "north", and the other called the "south", end.

The mill is further divided longitudinally on each floor by a center aisle or passage about 14 feet wide, the stairway between floors and a passenger and freight elevator near the fire-wall being the only interruptions.

Each half of the mill divided by this passage is complete in itself from cellar to attic, and is run by a separate turbine wheel, independent of the other half. This system allows one portion to be stopped for repairs without the necessity of suspending operations in the whole mill. The machines are arranged symmetrically on each side of the passage, and the drawings and description of one side are true of the other. The motive power of the mill is derived from two turbine wheels, each 55 inches in diameter, and expected to yield 1,000 horse-power under the head of 45 feet. From these wheels the power is distributed by two main shafts, one for each half of the mill, and by belting to the various floors and machines. The hands employed when the mill is in full operation will be in all 94, as follows: Employed in flour-making 49; millwrights, 10; sweepers, watchmen, rackmen, engineers, etc., 20; roustabouts, 15.

The system employed is the latest form of the "gradual-reduction" system, adopted after long and detailed experiment by the owner in his other mills. The wheat is brought to the mill by railway, and is conducted directly to storage-bins in the basement, of which there are forty, each of 2,000 bushels capacity, or a total capacity of 80,000 bushels. From these it is elevated and conveyed into the adjoining elevator-building, 35 by 94 feet in plan, and of the same height as the mill, having also a storage capacity of 80,000 bushels. All the wheat-cleaning apparatus is in this elevator, comprising the following machinery: Two large storage separators, which remove the grosser impurities, seven mill separators, and six double cockle-separators. The grain is then further cleaned by sixteen brush-machines, and graded into "small" and "large" wheat. The fuzz, etc., is then removed by ten run of ending-stones, five for each grade, and the resultant material is bolted on centrifugal reels, covered with wire-cloth, and separated.

The fine material from these centrifugal bolts goes to second low-grade flour. After granulation on the corrugated rollers of the first break, the wheat is scalped in four reels, the tailings, still containing the best part of the berry, being aspirated and conducted to the rollers of the second break. What passes through the bolting-cloth is divided into two streams and rebolted, and the flour thus separated is conducted to the low-grade flour-bins. The tailings of the flour-reels are separated into three grades by grading-reels, part mixed with other products and part further reduced by means of rollers, the resultant flour being of two grades: low grade and baker's grade. The middlings obtained from the boltings of the scalping-reels are brought to middlings grades and divided into ten distinct grades. These are then purified, reground on smooth rollers, and bolted. Wherever the same grades are produced they are mixed, and the operations thus simplified.

The wheat passes from one break to the other, in all six times, until the bran is absolutely free from all flour particles. The first break or reduction consists of four roller machines, the second of seven, the third of nine, the fourth of six, the fifth of four, and the sixth of three. The rollers of the earlier breaks are all of corrugated chilled iron. The second, third, fourth, and fifth breaks are treated similarly to the first, the best middlings being reground after purification on smooth porcelain rollers, and the finest flour made therefrom. The tailings from the last boltings are reground on stones. The grades of flour are six, and range from second low grade to superlative.

At present, there being only one-half of the mill in operation, the output is only about 1,700 barrels, the mill being designed to produce 4,000 barrels a day. A full inventory of machines in one-half the building is given below, to give an idea of the number and variety of machines necessary for producing the large amount of flour daily manufactured.

WHEAT-CLEANING MACHINERY.

2 elevator receiving-separators.	16 brush-machines.
7 wheat-separators.	10 run of ending-stones.
6 double cockle-separators.	3 wheat-graders.

MACHINES FOR REDUCING, BOLTING, ETC.

86 sets of rollers, as follows:	16 aspirators.
48 sets of corrugated iron.	148 bolting-reels.
26 sets of smooth iron.	10 sets of French millstones.
12 sets of porcelain.	14 graders.
78 middlings-purifiers.	38 sections of dust-rooms.

These machines are all driven by one of the turbines mentioned above.

Plates I and II have been copied from the working drawings of the mill, and show the position of the machinery and the transmission of power. In the basement or ground floor, directly upon the rock, rest the

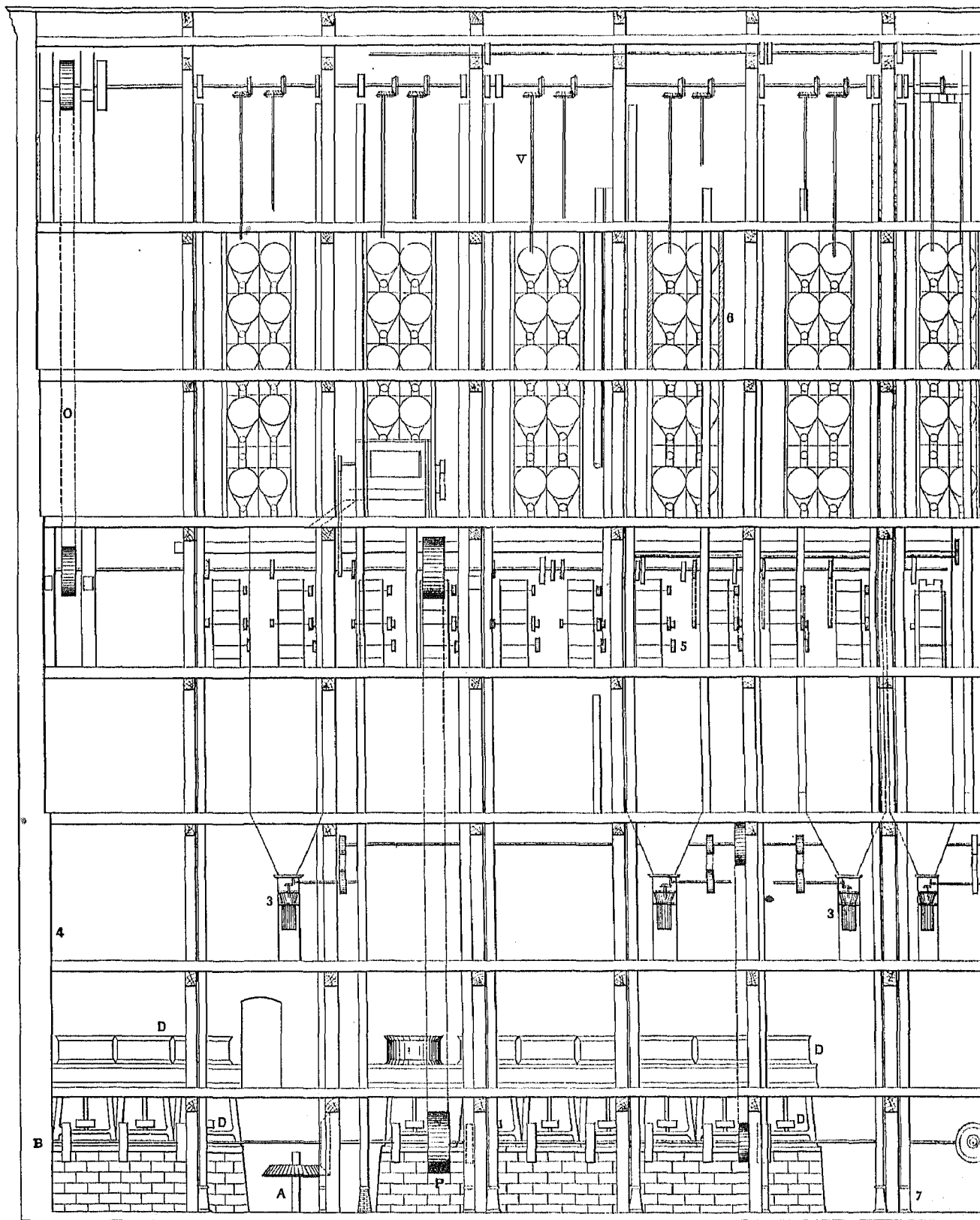


PLATE I.

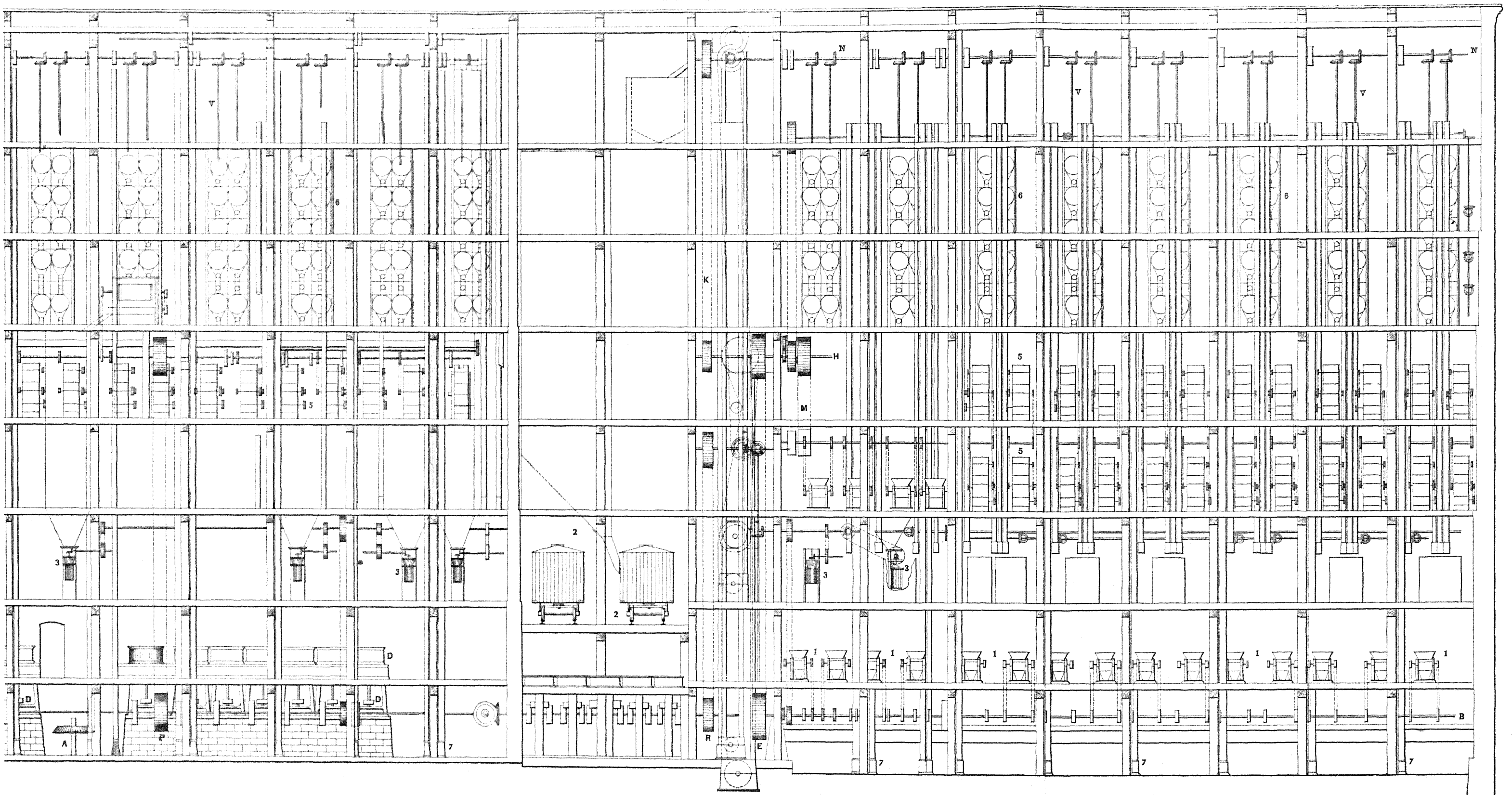
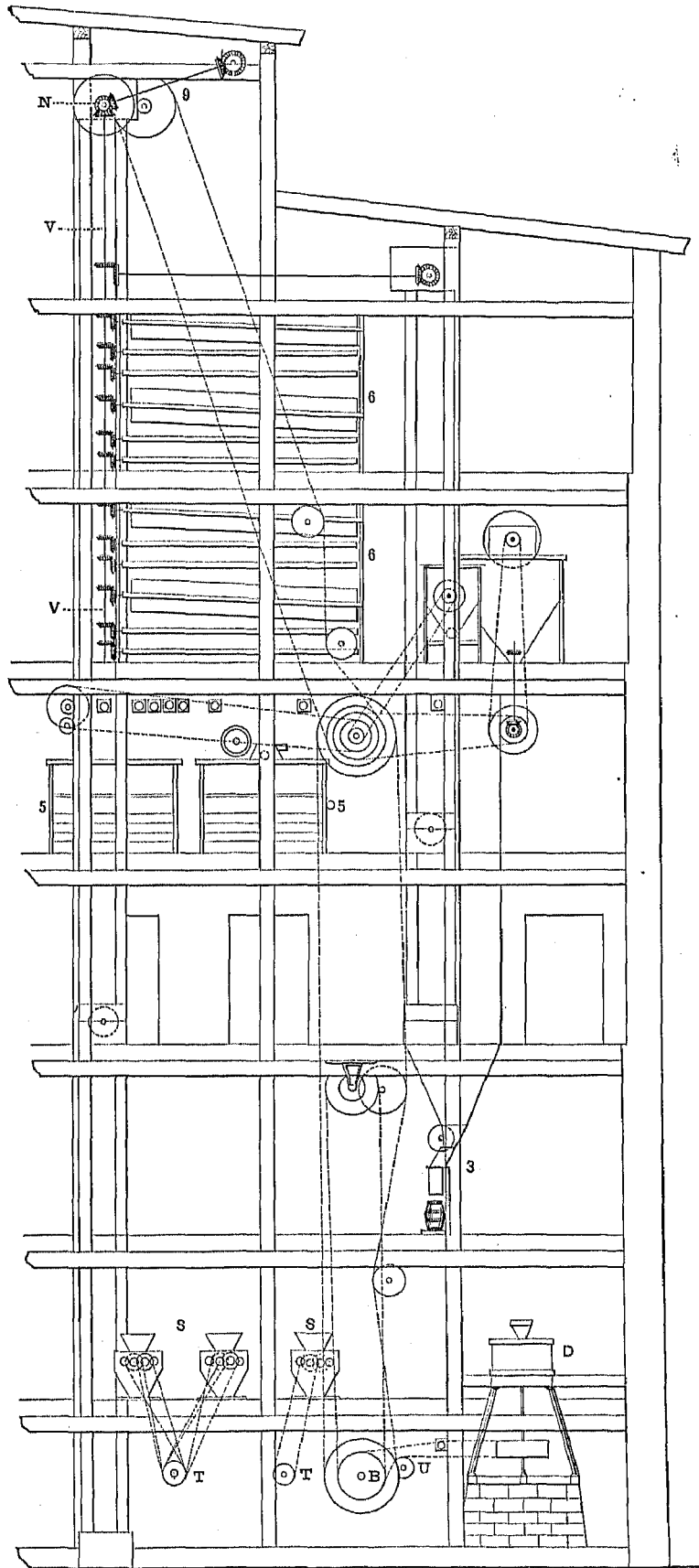


PLATE II.



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COULD NOT GET PLATE III
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PLATE IV.

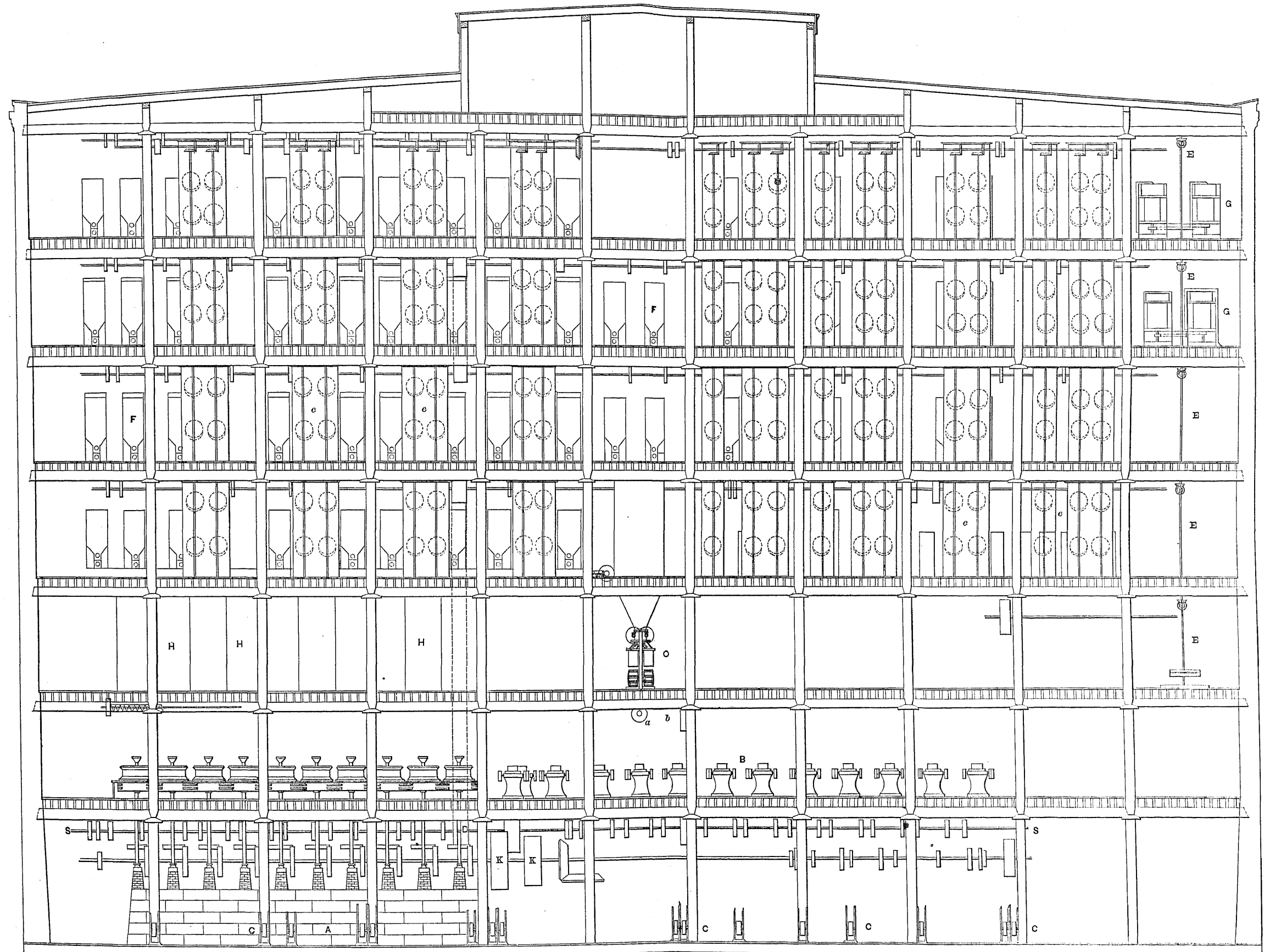


PLATE V.

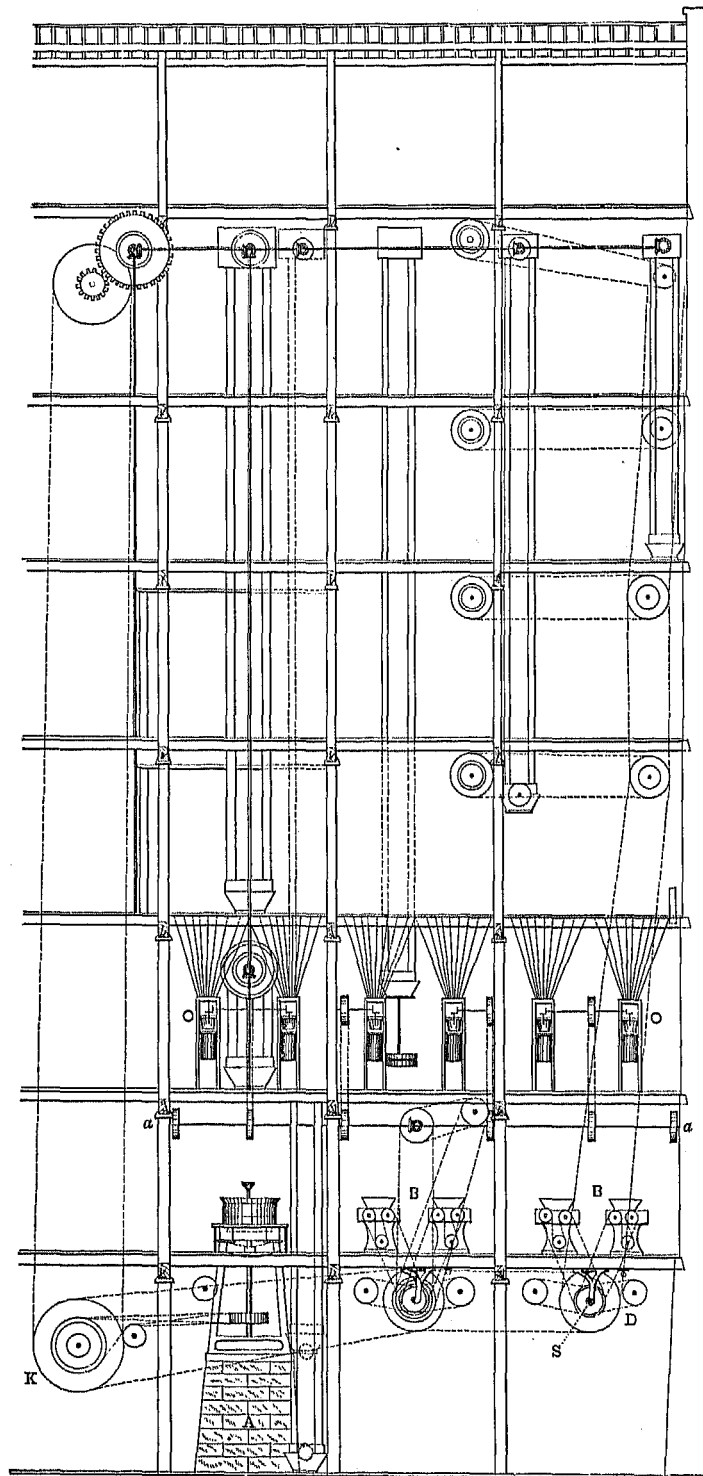
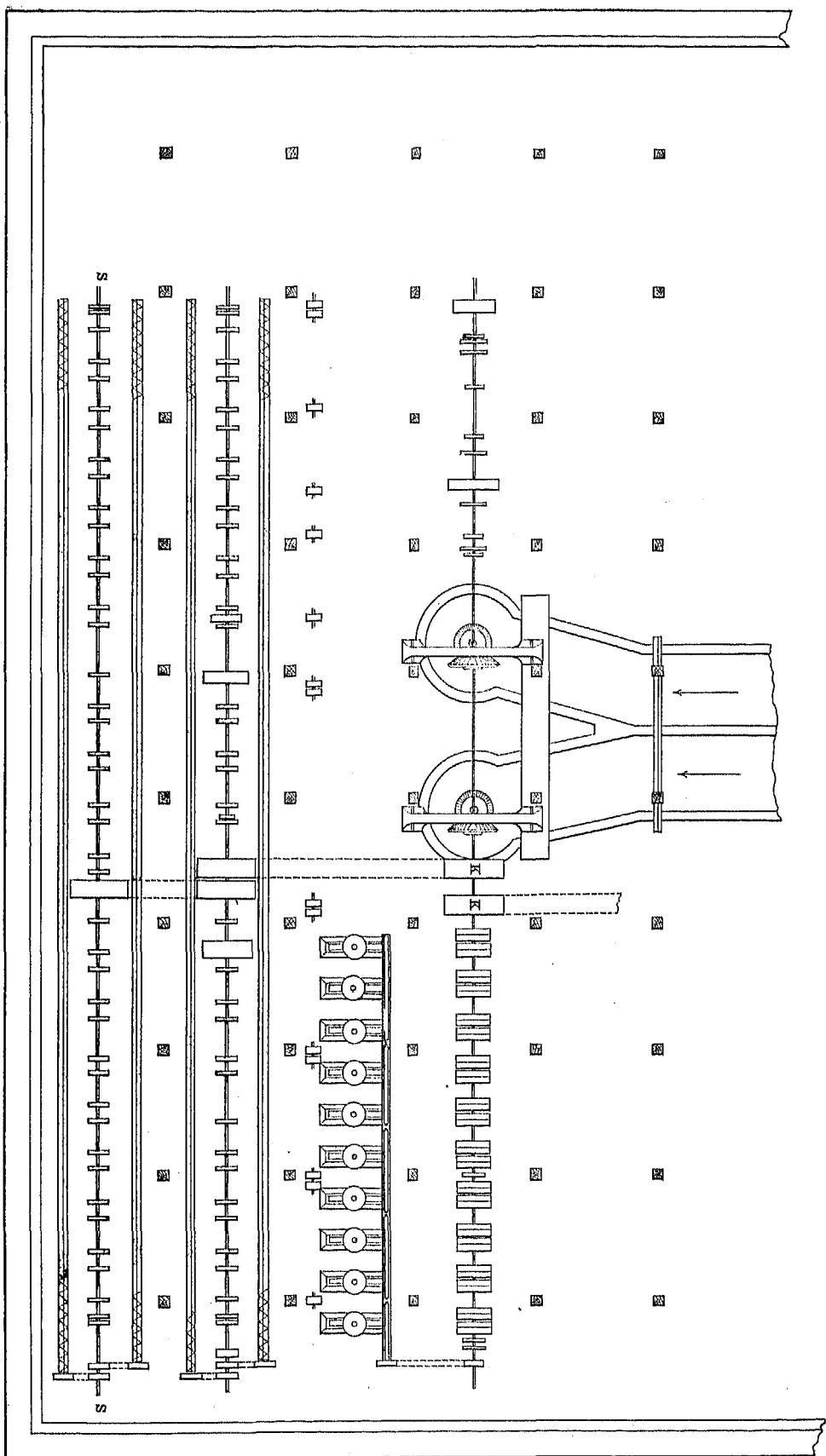


PLATE VI.



foundations for the millstone hursts, as shown in Plates I and II, and the foundations for the pillow-blocks of the main shaft B B, Plate I, which runs through from end to end of the mill, and to which the spindle-pulley of the stones D D D D are belted directly. The main gear and wheel-pit are located at A. The power for the south end of the mill is taken from the main shaft, from the pulley E, and distributed as follows:

E is belted to the pulley on the short shaft H, on the fifth floor, which in turn runs the shafting on the fourth and the eighth floors by the belts M and K. The latter furnishes the power to all the elevator heads on the eighth floor, as shown in the plate. The bolts on the fifth and sixth floors all run by vertical shafts, which are geared to the shaft N N. The rolls on the second floor are belted to the auxiliary shaft running near the ceiling of the basement and geared to the main shaft B B. The portion of the mill north of the brick fire-wall derives its power from the pulley P, which, similarly to E in the south portion, is belted to the shaft on the fifth floor; this in turn operating the bolting-reel shafts on the eighth floor, by means of the belt O, near the wall. The shafting on the packing floor is belted direct to the main shaft, as shown at R. On the seventh floor the purified middlings are carried from one end of the mill to the other by means of a car running over a track, the object being to transport the middlings from one end to the other without loss by friction, which would be considerable if a common conveyer were used. This deviation from the principles of automatic handling does not involve manual labor to any great extent, and saves a considerable amount in middlings.

The belting of the rollers and burrs is shown in Plate II. The rollers S S running together, require two belts (one being crossed), which are attached to the auxiliary shafts T T. The burrs, as stated before, run directly from the main shaft B, the belt being kept in position by the belt-tightener U. The bolts are operated by the shafts V V, which in turn take their power from the shaft N. The belting of the purifiers, of the graders, and Sturtevant fans is also shown in this plate. The portion of the mill over the car-track (the fourth floor) of the "north" part and the basement and the second floor of the "south" part are devoted in great measure to bins for wheat, bran, and flour. All the elevators throughout the mill are vertical, none whatever being set at an angle.

The flour, packed in barrels, is delivered to the cars by a simple arrangement, each barrel being allowed to run down an inclined plane, the velocity being checked by a heavy plank placed near the bottom, and pivoted at its upper end; by raising the top of the beam, in case a barrel stops entirely, the hand allows it to roll slowly into the car.

Plate I is a section through the central aisle of the mill, looking east. D D are the burrs, their hurst frames and foundations extending to the floor below; 1 1 are the corrugated iron rollers (their belting is seen better in Plate II); 2 2 are the tunnel and car-track for the incoming wheat; 3 3 are the packers; at the north end of the building, at 4, the fine grades of flour are loaded on the cars by the inclined plane previously described; 5 5 are the middlings-purifiers; these machines on both floors are belted to the same shaft in the fourth floor; 6 6 6 are the bolting-chests (the reels proper are omitted, to avoid complication in the plate); 7 7 are the elevators for raising the grain, middlings, etc. (the spouts, etc., are omitted).

Plate II is an elevation of the "north" end of the mill. At D is shown the end of the row of burrs; S S are the rollers; 3, the packers; 5 5, the purifiers; and 6 6 are sections of the bolting-chests, showing gearing, conveyers, etc. At 9 the gearing for reducing the speed of the bolt-shaft and the manner of gearing elevator-heads, etc., are shown.

To give a general idea of the immensity of the amount of material handled and the size of the mill, it may be stated that 621,125,000 cubic feet of masonry and 2,750,000 feet of lumber were used in its construction. When full it will hold 80,000 bushels of wheat, the amount ground daily being about 18,000 bushels. About 40,000,000 pounds of feed and \$4,000,000 worth of flour are produced annually. From 18 to 24 car-loads of wheat are daily unloaded at present, but when the mill is running to its full intended capacity of 4,000 barrels it will require over 50 car-loads of wheat every day. To ship the flour it will require daily 32 cars, and for bran, feed, and other offal it will need thirty additional cars, which will require the use of more than a hundred railroad cars every day. The bran is assorted into two qualities, fine and coarse, and is shipped for feed.

THE "PILLSBURY A" MILL.

This mill, now being erected on the eastern bank of the Mississippi at Minneapolis, will exceed, when completed, even the Washburn A in size, and it is believed will be the largest mill in one building in the world, the productive capacity having been placed at the enormous figure of 4,500 barrels per day. Similarly to the Washburn A, it is built of the granite so commonly used at Minneapolis, with high ceilings, many windows, and thick walls to insure steadiness and safety from fire. The floors are supported by pillars with iron capping plates, to prevent settling and the consequent disturbance to the lines of shafting. The power for moving the large number of machines will be derived from two Victor turbines, 54 inches in diameter, and under a head of 52 feet. It is expected by the builders and engineers that the power thus obtained will amount to 2,400 horse-power. The mill is of the most approved gradual-reduction type, and, like its great fellow on the opposite shore, is built on the dual plan, being

separated through the center, longitudinally, into two independent series of milling-machines. A "system", now constructed by all good millwrights and engineers before the final plans for a designed mill are completed, is shown for this mill in Plate III. This graphical representation of the path of the wheat from the first break to the packers gives a better insight into the process, even to the reader unversed in the details of milling, than any description, however explicit or minute.

Before describing it, however, a few words should be said of the grain cleaning, which, in plan, is to be much like that in the Washburn A. The wheat will be treated successively in the following machines, which will effectually remove all foreign and adherent matter: First, by two large storage separators; then by eight oat-separators; then, after grading into "small" and "large" wheat on four graders, by four cockle-separators, two for each grade; again by four scourers, by eight brush-machines, by four more separators, and finally it is ended on six run of ending-stones. The wheat elevated to the top floor descends through the various machines by gravity until it reaches the scourers on the third floor; from there it is elevated to the fifth floor, upon which the brushes are placed, and again descends to the final separators on the second floor. After this it is ready for crushing in the rollers. There will be five reductions or breaks, consisting of corrugated iron rollers, with the noiseless belting arrangement described in previous pages. The rollers will be divided as follows:

First break.—Seven sets of four-roller machines.

Second break.—Twelve sets of four-roller machines.

Third break.—Fourteen sets of four-roller machines.

Fourth break.—Ten sets of four-roller machines.

Fifth break.—Eight sets of four-roller machines.

After granulation on the first break, shown at A, Plate III, the broken wheat is bolted on the four scalping-reels, 2 2, and the separation between the resultant flour, middlings, and still unreduced particles of wheat is effected. The latter are treated in the four aspirators, 3 3, the shorts from which are conducted to the bin G; the clean broken wheat is then conducted to the second break, B, and the flour and middlings from the scalping-reels are conveyed to the bolting-reel 4. The narrow rectangle represents the conveyer of this bolt, and the line therefrom the path of the conveyer stuff or bolted material. The tailings, represented by the line starting from the end of the reel, are aspirated at 5 5 and conducted to the first germ-rollers, H. The bolted portion passes to the reels 6, 7, and 8; the tailings from 6, which are coarse middlings, run to the graders 9; the tailings from 7 (fine middlings) to the grading-reel 10; and finally the tailings from 8 to the stones IV. The product of reel 8 is the lowest grade of flour (Red Dog). From the grading-reel 9 the middlings produced on the first break are again graded on the sieves 11, treated by the air-machines 12; the resultant products, as shown in the plate, being three—the tailings and two grades of middlings. The former are purified in the two purifiers, 13, from which the shorts run to the bin G, and the purified middlings to the regrinding rollers, as shown in the plate. Of the two grades of middlings from the air-machines, one is run to the purifier 14, the other to the third germ-roller, K. The second, third, fourth, and fifth breaks are but repetitions of the first, as will be seen from the plate, the large amount of material to be handled causing the only difference—a greater number of each class of machines. The path of the various products and the points at which the same grades, or products requiring the same treatment, are mixed, can be traced without a detailed description of each break. It will suffice to say that A, B, C, D, and E are the five sets of reducing-rollers; G and G¹ the shorts and bran bins, respectively; I, II, III, IV, the regrinding burrs; V to XVI, inclusive, the final sets of bolts; H, I, K, the first, second, and third germ-rollers; and L, M, N, O, and P, five sets of crush-rollers. The grades of flour produced and their names are given at the barrels on the lower end of the plate. They are "low grade" (Red Dog) from the first break; 2d baker's from the bolts XVI; 1st baker's from the second break and the bolts VII and XV; the second patent (a) from the bolts VIII and IX; another grade of 2d patent (b) from the germ-rollers and bolts V and VI, and finally the highest grade, or 1st patent, as it is called, from the bolts X to XIV. A good idea may be derived from the foregoing of the intricacy of the gradual-reduction system, and of the knowledge of the action of the various machines necessary to design a mill of large dimensions; the results of the various boltings, the appropriate mesh of the cloth, etc., necessitate, as may be easily imagined, a study and practical experience of many years.

A full list of machines for half the building, or one complete milling system, is here given:

WHEAT-CLEANING MACHINES.

2 storage separators.	8 brush-machines.
2 oat-separators.	6 run of ending-stones.
4 double cockle-separators.	6 reels.

MACHINES FOR REDUCING, BOLTING, ETC.

94 sets of rollers, viz:	20 aspirators.
38 sets of smooth iron.	100 middlings-purifiers.
6 sets of porcelain.	Air-machines.
50 sets of corrugated iron.	Packers on flour.
10 run of burrs.	2 packers on bran.
170 reels.	Sections of dust-rooms.

The transmission of power from the wheels to the various machines is very similar to that in the Washburn A, but as there is no transverse wall, the system is somewhat simplified. The power derived from the two turbines, as stated above, is distributed from the main shaft in the basement to the various floors, the stones on the grinding floor being run directly from it. The bridge-tree, miter-gear, race-way, and shafting are shown on Plate VI. The arrangement of T-beams across the head-races for the support of the pillars and the floors above, and the support of the bridge-tree by the arch, are also shown. From the shaft S S the power taken off at D, Plate V, by the main belt, which runs to the fourth floor, where it operates the entire line of shafting. This in turn is belted to the line on the fifth floor, the line on the fifth to the line on the sixth, and the line on the sixth to the shafting on the seventh, which operates all the bolts and grain-cleaning machinery on the third, fourth, fifth, and sixth floors by means of the vertical shafts E E E, Plate IV, geared to it. The main shaft is belted to the auxiliary shaft by means of the pulleys K K. The detailed belting of the various machines will be easily understood from a perusal of the plates.

Plate IV is a longitudinal elevation through the center of the mill, showing at A the foundation, belting, and position of the millstones; at B the rollers and their belting from the auxiliary shaft in the basement; at C C C the elevator-feet, which are broken to avoid complication in the plate; at O the double row of packers extending across the mill and run from the shaft *a* on the floor below (*a* is geared to *b*, and *b* belted to the auxiliary shaft in the basement); at *e e e* the bolting-reels in their chests, actuated by the vertical shafts; at F F the middlings-purifiers, partly concealed by the bolting-chests in front; at G G the various grain-cleaning appliances run by the vertical shaft E; at H H the middlings- and flour-bins, and finally the wheat storage-bins, occupying the four lower right-hand compartments of the plate.

Plate V is an end elevation, showing the main shaft; the foundation and hurst frames of the stones; the belting of the rollers, packers, and grain-cleaning machinery; also the gearing in the seventh floor to obtain the slow motion of the vertical bolt-shafts.

Plate VI is a plan of the basement, showing the race-way, main gears, main shaft, conveyers, etc.

RECAPITULATION.

If we look over the field covered by the preceding pages we see that there are altogether, at present, three processes of manufacturing flour in this country, viz:

- a. Crushing the grain to flour between millstones by a single grinding, and then bolting out the bran and coarse matter.
- b. Granulating the wheat by millstones or rollers, separating the resultant middlings, purifying and grading them, and finally regrinding them to flour.
- c. Granulating the wheat very coarsely, mostly or entirely by rollers, separating the middlings, flour, broken wheat, etc., thus formed, again reducing the fragments of broken wheat, separating and repeating the operation several times, more completely separating bran and flour.

As previously stated, there are other processes introduced by individuals, but in general they are but modifications of these systems.

The two new systems have been introduced in many mills, and have attained much celebrity since the publication of the Ninth Census (1870). In fact they have obtained so many enthusiastic supporters that at present none of the larger mills are being erected on the old system. It is, however, the opinion of those who have watched the various milling systems in Europe that high grinding is adapted chiefly to hard wheats, medium high (or "new" process) to wheats of a greater tenacity of bran and starchiness of endosperm, while the "old" or low process is economically applicable only to very soft winter wheats and for small country and frontier mills.

The great change from low to medium high and high grinding was caused by the impossibility of producing flour of the best market standing by low grinding from the hard spring wheat of the northwest, and the consequent adoption of the two new processes. These in turn being highly successful were tried on wheat of a softer nature and were found to operate satisfactorily, enabling the millers not only to produce their flour more economically, but to name it "patent", for which there has been and yet continues to be a preference in the market.

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